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ACKNOWLEDGEMENTS

This study was truly a collaborative effort among agencies, entities, and individuals and required an enormous amount of time, resources, and dedication. We first thank our co-author and original investigator for this project, Grant Grisak; his devotion to the resource and those who use it is unparalleled and inspirational. We also thank our co-author Jason Mullen for his guidance, patience, and commitment to seeing this project through. In addition to data analysis and review, Brian Tornabene provided enthusiasm and encouragement. We are indebted to Michael Duncan for his thorough review, support, and advice. Michael Lance and Al Zale contributed both writing advice and knowledge of the Smith River system. Katie Vivian provided guidance and insights on salmonid movements and water temperatures. Dave Stagliano contributed data. Numerous individuals assisted with equipment installation and upkeep, fish marking, and data management: Rob Clark, Tracy Elam, Rob Beattie, Mike Schilz, Gabe Madel, Keenen Blackbird, Jonathan Wester, Charlie Williams, Lauren Flynn, Katie Vivian, Dylan Owensby, Colton Wennerberg, and Megan Heinemann. Colin Maas and his Smith River State Park personnel provided insights and support. Finally, this project would not have been possible without the cooperation of private landowners in Cascade, Meagher, and Lewis and Clark counties and the Lewis and Clark National Forest Service.

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ABSTRACT

The upper Missouri River below Holter Dam consists of three primary interconnected salmonid populations that provide important recreational sport fisheries. Despite the presence of the myxosporean parasite Myxobolus cerebralis, the upper Missouri River rainbow trout Onchorhynchus mykiss population is among the most productive fisheries in the state. Previous studies have suggested that diverse life history patterns may explain the resilience of trout populations to the parasite. We used passive integrated transponder (PIT) telemetry to investigate outmigration timing, spawning strategies, straying and homing rates, and aging and growth patterns. Outmigration varied among species and tributaries but was generally bimodal and usually occurred following sudden changes in stream discharge. Our analysis implicated photoperiod and discharge as factors influencing outmigration, but primary drivers in some systems were unclear; multiple linear regression models explained only up to 14% of variation in outmigration. In the upper Missouri River, relatively few tagged fish were observed spawning in tributaries, suggesting mainstem spawning may be widespread. Rainbow trout spawning occurred primarily in the Little Prickly Pear Creek watershed in the Missouri River and Sheep Creek watershed in the Smith River. Brown trout Salmo trutta spawning was restricted to the Little Prickly Pear Creek watershed in the Missouri River but was distributed widely among tributaries in the Smith River. Mountain whitefish Prosopium williamsoni spawned almost exclusively in the Dearborn River watershed in the Missouri River and in the Sheep Creek and Tenderfoot Creek watersheds in the Smith River. No spawning was observed in the Sun River. Consecutive and alternate year spawning was observed in all species. Stray rates of tributary spawners were much lower than expected based on previous studies of mainstem spawners and ranged from 1% to 7% at the watershed scale and 16% to 51% at the subwatershed scale. Minimum homing rates were generally greater than straying rates, but many fish could not be categorized or were unaccounted for and could have been tributary residents, mortalities, or undetected. Growth rates were highest in the upper Missouri River subbasin and averaged 71 mm (2.8") per year over an average interval of 3.5 years for rainbow trout and 88 mm (3.5") per year over an average interval of 3.4 years. Longevity was highest in the Smith River subbasin where rainbow trout potentially reached seven to eight years of age. Mountain whitefish were the longest-lived species reaching over ten years of age. Life history patterns were potentially more diverse than previously thought. Such complexity promotes a resilient and robust fishery in a climatically dynamic system.

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1	CHAPTER ONE
2	
3	INTRODUCTION
4	
5	Knowledge of life history patterns is necessary for effective management of salmonid
6	populations, but such patterns can be complex and vary across biological, spatial, and temporal
7	scales (Bennett et al. 2014; Lance 2019). Life history diversity in potomadromous populations is
8	thought to have evolved in response to dynamic systems in which spatial and temporal
9	availability of resources varies greatly (Gresswell et al. 1994; Northcote 1997). Such populations
10	are therefore more robust because connectivity from diverse movement patterns promotes
11	resilience to environmental disturbances (Dunham and Rieman 1999).
12	Outmigration timing, spatial and temporal distribution of spawning, and age structure are
13	primary aspects of salmonid life history, but literature on such topics in the context of large
14	inland populations is uncommon (Bennett et al. 2014). Most current knowledge is skewed
15	towards either anadromous populations (Keefer and Caudill 2014) or potomadromous trout of
16	adfluvial populations (Downs et al. 2006; Watschke 2006; Bennet et al. 2014). Accordingly, life
17	history of fluvial salmonids has been identified as an area requiring further investigation (Al-
18	Chokachy and Budy 2008; Bennet et al. 2014).
19	In the upper Missouri River basin, fluvial salmonid populations support popular
20	recreational fisheries, including the Holter Dam tailwater fishery and the only permitted float in
21	Montana on the Smith River. The Holter Dam tailwater fishery in the upper Missouri River is
22	among the most productive rainbow trout Onchorhynchus mykiss populations in Montana and
23	consistently ranks among the most heavily fished waters in the state (183,479 angler days in
24	2015; Montana Fish, Wildlife & Parks [FWP] 2015). In 1995, the myxosporean parasite

Myxobolus cerebralis that causes whirling disease was discovered in one of the primary rainbow
trout spawning tributaries, Little Prickly Pear Creek. The parasite subsequently spread to
additional spawning tributaries over the next several years (Grisak 1999; Leathe 2001). Although
whirling disease contributed to sharp declines in rainbow trout populations in the Madison and
Colorado rivers (Vincent 1996; Nehring and Walker 1996), rainbow trout abundances remain
stable in the Missouri River.

31 The robustness and resilience of this tailwater fishery is thought to be the result of 32 complex life history patterns. Accordingly, investigations on outmigration timing, spawning 33 distribution, and age structure were conducted. Outmigrations of juvenile rainbow trout and 34 brown trout Salmo trutta from Little Prickly Pear Creek and the Dearborn River were examined 35 using a rotary screw trap from 1998 to 2002 (Leathe 2001; Leathe et al. 2014). Outmigration 36 patterns were variable and influenced by a variety of environmental factors (Leathe et al. 2014). 37 Scale patterns were used to determine that age-1 outmigration life history was the most common 38 outmigration strategy of juvenile rainbow trout in Little Prickly Pear Creek and the Dearborn 39 River (Munro 2004). Multiple radiotelemetry studies have demonstrated a lack of spawning site 40 fidelity in rainbow trout tagged in the mainstem Missouri River (Grisak et al. 2012b) and 41 evidence of interconnected populations among Missouri River, Sun River, and Smith River 42 rainbow and brown trout (Grisak et al. 2012a). Finally, a 30-year scale aging study on rainbow 43 and brown trout in the upper Missouri River revealed relatively high growth rates based on 44 length at age data.

Though extensive, previous studies were conducted in different years and over relatively
short durations, leaving gaps in knowledge of salmonid life history patterns in the basin. A
comprehensive understanding would enhance management of salmonids in the basin and could

48 provide insights into the resilience of salmonid populations to environmental disturbances such 49 as whirling disease. In 2013, Northwestern Energy awarded Montana Fish, Wildlife & Parks 50 funding to use passive integrated transponder (PIT) telemetry to monitor fish movement in the 51 upper Missouri, Sun, and Smith rivers. Our goal was to investigate the life histories of rainbow 52 trout, brown trout, and mountain whitefish *Prosopium williamsoni*. Our objectives were to (1) 53 quantify spatiotemporal variability of natal straying and homing rates and identify connectivity 54 among upper Missouri River, Sun River, and Smith River salmonid populations, (2) determine 55 the timing of and factors influencing rainbow and brown trout outmigration, and (3) determine 56 growth rates and age structures of rainbow trout, brown trout, and mountain whitefish 57 populations and compare them to previous age and growth studies. 58 A concurrent study investigating salmonid movement and connectivity in the Smith River 59 (Lance 2019) provided a unique opportunity to examine inter-subbasin connectivity and compare 60 life history patterns among the upper Missouri, Smith, and Sun rivers. Although funding awarded 61 by Northwestern Energy was not used for this Smith River study, the interconnected nature of 62 the salmonid populations warranted report of some results and comparisons. In addition, a study 63 examining rates of predation on Smith River trout by American white pelicans Pelecanus 64 erythrorhynchos was conducted from 2016 through 2017 (Vivian and Mullen 2018). Although 65 this study is referenced in our report and some findings are presented, we did not include detailed 66 results. Details of the pelican predation study and comprehensive annual summaries of this life 67 history study can be found in Vivian and Mullen (2008) and Mullen et al. (2017), Mullen et al. 68 (2018), and Mullen and Vivian (2019), respectively.

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- 70

Study area

71 Upper Missouri River

72 The upper Missouri River is in central Montana and originates at the confluence of the 73 Jefferson, Madison, and Gallatin rivers (Figure 1.1), extending north to Loma, Montana, where 74 the river begins to flow east. The upper Missouri River basin has a drainage area of 36,248 km² 75 and has two major tributaries, the Sun River and Smith River. The study area begins at Holter 76 Dam and extends north to the confluence of the Missouri and Sun rivers near Great Falls, 77 Montana (Figure 1.1). In addition to Holter Dam, two other hydroelectric dams (Hauser and 78 Canyon Ferry) regulate discharges in the upper Missouri River; mean daily discharge measured 79 below Holter Dam was 6,639 CFS from 1955 to 2020 (USGS site 06066500). Smaller tributaries in the study area include Little Prickly Pear Creek, Sheep Creek, and the Dearborn River. 80 81 Little Prickly Pear Creek flows east into the Missouri River 3.8 km downstream of Holter 82 Dam (Figure 1.1). Draining an area of 1,026 km², Little Prickly Pear Creek has two major 83 tributaries, Wolf and Lyons creeks. Mean daily discharge from 1988 to 2020 was 49 CFS (USGS 84 site 06071300). Little Prickly Pear Creek and its tributaries are used heavily as spawning areas 85 by rainbow and brown trout (Grisak 1999; Grisak et al. 2012; Leathe et al. 2014). 86 The Dearborn River originates on the eastern slope of the Rocky Mountain Front and 87 enters the Missouri River from the west near the town of Craig, Montana (Figure 1.1). The Dearborn River drains an area of 1,418 km². Mean daily discharge was 63.6 CFS from 1969 to 88 89 2020 (USGS site 06073500). The Dearborn River is an important spawning tributary for rainbow 90 and brown trout (Grisak 1999; Grisak et al. 2012; Leathe et al. 2014). 91 Sheep Creek begins on the western slope of the Big Belt Mountains before entering the 92 Missouri River 37.8 km downstream of Holter Dam (Figure 1.1). Sheep Creek is a smaller 93 tributary relative to Little Prickly Pear Creek and the Dearborn River, draining an area of 96 km².

Discharge data were not available for Sheep Creek. Rainbow and brown trout also use Sheep
Creek as a spawning area (Grisak 1999; Grisak et al. 2012; Leathe et al. 2014).

96

97 Sun River

98 The Sun River originates in the Bob Marshall Wilderness on the eastern slope of the 99 Rocky Mountain Front and flows east until its confluence with the Missouri River near Great 100 Falls, Montana. The Sun River drainage area is 4,863 km². The study area begins below the Sun 101 River Diversion Dam, which is a complete barrier to movement 5.6 km downstream of Gibson 102 Dam, and extends to the confluence, including one major tributary, Elk Creek (Figure 1.1). The 103 Sun River is used extensively for irrigation and several diversion dams in its lower reaches 104 potentially limit fish movements during low flows (Figure 1.1). Mean daily discharge taken near 105 Simms, Montana from 1987 to 2020 was 205 CFS (USGS site 06085800). 106 Elk Creek originates in the Lewis and Clark National Forest south of the Sawtooth Range 107 and flows northeast until its confluence with the Sun River near Augusta, Montana (Figure 1.1). 108 The drainage area of Elk Creek is 501 km². Discharge data were not available. 109 110 Smith River 111 The Smith River originates near White Sulphur Springs, Montana, and flows northwest

for 195 km to its confluence with the Missouri River near Great Falls, Montana (Figure 1.1). The Smith River drains an area of 5,190 km² from tributaries flowing out of the Castle, Big Belt, and Little Belt mountains. Mean daily discharge measured near Fort Logan from 1996 to 2020 was 106 CFS (USGS site 06077200). A river corridor managed in partnership with federal, state, and private landowners as Smith River State Park extends from the only recreational put-in at Camp Baker 95 km to the only take-out at Eden Bridge. Major tributaries of the Smith River includeSheep, Tenderfoot, and Hound creeks (Figure 1.1).

Sheep Creek originates in the Little Belt Mountains, flowing west until entering the Smith River just downstream of Camp Baker (Figure 1.1). The drainage area of Sheep Creek is 504 km². The study area included one major tributary, Moose Creek. Discharge data for Sheep Creek were not available. Rainbow trout and mountain whitefish use Sheep Creek and its tributaries extensively for spawning (Lance 2019).

Tenderfoot Creek originates on the western slope of the Little Belt Mountains, entering the east side of the Smith River 26 km downstream of Camp Baker (Figure 1.1) and drains an area of 282 km². The study area consisted of Tenderfoot Creek and several tributaries below a waterfall barrier 13.7 km upstream of the confluence with the Smith River that prevents upstream fish movements (Figure 1.1). Discharge data were not available. Rainbow trout and mountain whitefish use lower Tenderfoot Creek extensively for spawning; brown trout spawn there to a lesser extent (Ritter 2015).

Hound Creek is the lowest major tributary of the Smith River, flowing northeast out of the foothills of the Big Belt Mountains until its confluence with the Smith River 2.6 km upstream of the Eden Bridge take-out (Figure 1.1). The drainage area is 592 km². Discharge data were not available. Rainbow trout, brown trout, and mountain whitefish moved into Hound Creek during spawning seasons, suggesting some use as a spawning area (Lance 2019).

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137 Fish assemblage

The fish assemblage of the study area includes mountain whitefish, brown trout, rainbow
trout, westslope cutthroat trout *Onchorhynchus clarkii lewisi* (mostly restricted to isolated

tributaries in the Smith River subbasin), hybridized cutthroat trout, and brook trout *Salvelinus fontinalis*. Other game fishes include burbot *Lota lota*, yellow perch *Perca flavescens*, walleye *Sander vitreus*, and northern pike *Esox lucius*. White suckers *Catostomus commersonii*, longnose
suckers *Catostomus catostomus*, and mountain suckers *Catostomus platyrhynchus* are common
throughout the study area. Rocky Mountain sculpin *Cottus bondi* and longnose dace *Rhinichthys cataractae* are also common throughout the study area and numerous other non-game species are
also present.





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150 Figure 1.1. The upper Missouri, Sun, and Smith rivers and their major tributaries. Yellow dots

represent USGS gaging stations used in the study. Black diagonals represent dams or diversions.

- 152 Green diamonds represent fixed PIT antenna arrays. Shaded buffers represent areas where fish
- 153 movement was monitored by fixed PIT antenna arrays, portable PIT antennas, and physical
- 154 recapture events.
- 155

156 CHAPTER TWO 157 158 SPATIOTEMPORAL VARABILITY OF NATAL STRAYING AND HOMING RATES AND 159 CONNECTIVITY AMONG UPPER MISSOURI RIVER, SUN RIVER, AND SMITH RIVER 160 SALMONID POPULATIONS 161 162 Introduction 163 164 Potomadromous trout populations demonstrate a variety of spawning patterns, including 165 adfluvial (outmigration from natal streams as juveniles to lakes; Downs et al. 2006; Watschke 166 2006), fluvial (outmigration from natal streams as juveniles to larger rivers; Al-Chokachy and 167 Budy 2008; Bennett et al. 2014), and tributary residence (Hilderbrand and Kershner 2000; Ritter 168 2015). Multiple spawning patterns can occur within populations and even drainages (Gresswell 169 et al. 1994; Al-Chokachy and Budy 2008). In extensive, interconnected river basins, variations

170 within fluvial spawning patterns have been observed. In some populations, individuals move

171 great distances to spawn in mainstem river habitat rather than natal tributaries (DeRito et al.

172 2010). Adults may share mainstem river habitat to exploit metabolic benefits but home to

173 separate natal streams to spawn (Kershner et al. 2019).

Diversity in spawning patterns has enabled salmonids to colonize dynamic coldwater habitats that experience spatially and temporally variable environmental disturbances (Dunham and Rieman 1999; Kershner et al. 2019). Accordingly, the robustness and productivity of fluvial salmonid populations in the upper Missouri River basin in the presence of whirling disease are thought to be products of highly variable spawning patterns. Radiotelemetry studies investigating the spawning characteristics of rainbow trout showed interannual variation in spawning locations and low spawning site fidelity (Grisak et al. 2012b). Radio-tagged fish spawned in both the

181 mainstem Missouri River and tributaries (Grisak et al. 2012b). Redd counts showed 72% of 182 spawning occurred in tributaries, primarily Little Prickly Pear Creek and its tributaries, but 183 mainstem spawning was more prevalent than observed in previous studies (Grisak et al. 2012b). 184 In addition to spawning patterns, radiotelemetry studies revealed an interconnectivity 185 among the upper Missouri, Sun, and Smith rivers (Grisak et al. 2012a). Multiple rainbow and 186 brown trout were observed moving from the Missouri River to the Smith River and its tributaries 187 to spawn (Grisak et al. 2012a). The relatively low total number of fish tagged (N = 43) suggested 188 that such inter-subbasin movement may not be uncommon (Grisak et al. 2012a). 189 We used PIT telemetry to monitor fish movement in the upper Missouri, Sun, and Smith 190 rivers. Our goal was to investigate the spawning patterns and movement of rainbow trout, brown 191 trout, and mountain whitefish. Our objectives were to quantify spatiotemporal variability of natal 192 straying and homing rates and identify connectivity among upper Missouri River, Sun River, and 193 Smith River salmonid populations. 194 195 Methods 196 197 **PIT-tagging** 198 A total of 11,936 fish was tagged in the upper Missouri River basin from 2010 to 2019; 199 3,572 in the upper Missouri River subbasin (Table 2.1), 739 in the Sun River subbasin (Table 200 2.2), and 7,625 in the Smith River subbasin (Table 2.3). From 2010 to 2012, 777 fish were 201 tagged as part of a Montana State University graduate study investigating Tenderfoot Creek, a 202 major tributary of the Smith River (Ritter 2015). Most of these fish were likely not present from

203 2014 to 2019; however, some fish tagged in 2012 were active until at least 2018 (Mullen and
204 Vivian 2019).

205 Fish were collected with boat, barge, and backpack electrofishers, and fyke nets, 206 anesthesized with Aqui-S 20E (Aqui-S New Zealand Ltd.; 10 to 20 mg/L) or MS-222 (tricaine 207 methanesulfonate; 50 mg/L), and implanted with half duplex (HDX) PIT tags. Location, species, 208 and total length (TL) were recorded for each fish at the time of tagging; 20% (2,389 of 11,936) 209 were also weighed. The date when a fish was collected and tagged was recorded as the first 210 observation for each individual. PIT tags were surgically implanted into the abdominal cavity 211 through small incisions made by a small scalpel coated with antiseptic. Most fish were tagged 212 with 23 or 32-mm HDX PIT tags; a small number of fish (217 of 11,936) were tagged with 12-213 mm HDX PIT tags.

214

215 Monitoring fish movement

216 A network of 23 stationary PIT arrays monitored the movements of PIT-tagged fish 217 throughout the upper Missouri River basin (Table 2.4 and Figure 2.1). Five arrays were installed 218 in the upper Missouri River in the spring of 2014, three arrays were installed in the Sun River in 219 the spring of 2015, and 15 arrays were installed in the Smith River from 2014 to 2016 (Table 2.4 220 and Figure 2.1). These monitoring stations ran in some combination from 2010 to 2019 (Figure 221 2.2). The Dearborn River, Little Prickly Pear Creek, Truly Bridge (Smith River), and Hound 222 Creek arrays were damaged by flows in the spring and early summer of 2018. All but Truly 223 Bridge were repaired and reinstalled. Five stations were operated in Tenderfoot Creek from 2010 224 to 2014, but only one array installed at the mouth of Tenderfoot Creek was maintained after 2013 225 (Table 2.4 and Figure 2.1; Ritter 2015). Age and growth analyses used data collected prior to

2014 and afterward, but all other analyses were restricted to data collected after 2013. In general,
fixed PIT arrays were installed in locations to monitor interchange between tributaries and
mainstem rivers. Array locations were not necessarily conducive to monitoring interchange
among the Missouri River, Smith River, and Sun River subbasins (Figure 2.1). The Truly Bridge
PIT array was in the most favorable location to monitor such movement but was still 14.6 rkm

231 (9.1 miles) from the confluence of the Smith River with the Missouri River (Figure 2.1).

232 Antenna stations consisted of a PIT-tag reader (Oregon RFID, multi-antenna HDX reader 233 and long-range HDX reader, Portland, Oregon), one to two stream-width antennas, and a tuning 234 board for each antenna (Oregon RFID, standard remote tuner board and long-range tuner board, 235 Portland, Oregon). Antenna arrays were powered by 12-V DC supplied by either solar panels or 236 120-V AC converters. Antennas were placed in areas where fish would unlikely stay for long 237 periods of time (e.g., riffles and shallow water habitat) to prevent many consecutive detections 238 and to monitor interchange between mainstem river and tributaries (rather than localized use near 239 the antennas). All antennas were oriented flat on the bottom (swim over or flat-bed design; 240 Armstrong et al. 1996) and tuned to best possible vertical read ranges for tags oriented 241 perpendicularly to the antennas. Average tag detection distances of antennas ranged from 0.03 to 242 1.50 m (Table 2.4) and varied seasonally (Figure 2.3). Detection efficiencies (Zydlewski 2006) 243 of PIT arrays installed in the Smith River ranged from 0.66 to 1.00 (Lance 2019). Detection 244 efficiencies can be used to correct for potential bias associated with variations in detection 245 efficiencies of stationary PIT arrays (e.g., Lance 2019). We did not account for such bias in this 246 study; rather, we provided detection efficiencies as a metric for PIT array performance in 247 addition to tag detection distance.

248	Mobile PIT arrays were used to actively monitor fish movements and complement the
249	network of fixed monitoring stations. Mobile tracking was conducted using raft, kayak, and pole-
250	mounted antennas (Hill et al. 2006; McKinstry and Mackinnon 2011); methods are explained in
251	detail by Lance (2019). In the upper Missouri and Sun rivers, mobile tracking by raft and kayak
252	was conducted in 2015 and 2016 but discontinued thereafter because of low detection range. A
253	pole-mounted antenna was used in 2016 to scan tributaries and islands of the upper Missouri
254	River and American white pelican Pelecanus erythrorhynchus nesting islands in Canyon Ferry
255	and Arod Lake (Vivian and Mullen 2018). In the Smith River, all forms of mobile tracking were
256	used to track fish from 2015 to 2017 (Lance 2019). No mobile tracking was conducted from
257	2018 onward.
258	
259	Data analysis
260	
261	The statistical software programs R (v4.0.2; R Core Team 2019) and SigmaPlot 14
262	(SigmaPlot 2017) were used for analyzing and plotting trends and comparisons in outmigration
263	timing and magnitude, straying and homing rates, and age and growth rates. Program R was also
264	used for modeling water temperatures. We used geographic information system (GIS) software
265	(QGIS 2021) for spatial analyses and map construction.
266	
267	Spatial analysis
268	We divided the study area into hydrologic units based on the hierarchical hydrologic unit
269	code (HUC) system developed by the USGS at four different levels: basin, subbasin, watershed,
270	and subwatershed (Figures 2.4, 2.5, and 2.6). Locations of fish determined by fixed PIT arrays,

portable PIT tracking events, and physical capture events were joined with hydrologic units for
spatial analysis (Figure 2.7). The upper Missouri River basin encompasses five subbasins: upper
Missouri-Dearborn, upper Missouri River, Sun River, Smith River, and Belt Creek. Because the
study area included parts of both the upper Missouri-Dearborn and upper Missouri River
subbasins, we combined them to simplify analysis and hereafter refer to them collectively as the
upper Missouri River subbasins.

277 Seven of the 42 watersheds in the upper Missouri River subbasins were included in 278 analyses (from upstream to downstream): Rattlesnake Gulch, Little Prickly Pear Creek, Stickney 279 Creek, Dearborn River, Sheep Creek, Castner Coulee, and City of Great Falls (Figure 2.4). 280 Sixteen subwatersheds were included in the study: Medicine Rock, Little Prickly Pear Creek, 281 Lyons Creek, Log Gulch, Wolf Creek, Dog Creek, Dearborn River, Sheep Creek, Finigan Creek, 282 Antelope Creek, Knapp Creek, Lower Chestnut Valley, Nelson Island, Wilson Butte, and City of 283 Great Falls (Figure 2.4). The Dog Creek and Finigan Creek subwatersheds encompass the 284 Cascade and Craig sections, respectively, used by Montana Fish, Wildlife & Parks for annual 285 population sampling (Figure 2.4).

Five of the eight watersheds in the Sun River subbasin were included in analyses: Gibson Reservoir, Elk Creek, Dry Creek, Big Coulee, and Fourmile Creek (Figure 2.5). Location data of fish in the Sun River were too coarse to be analyzed at the subwatershed scale. The Big Coulee watershed encompassed the Simms section used by Montana Fish, Wildlife & Parks for annual population sampling (Figure 2.5).

All 11 Smith River watersheds were included in analyses: North Fork Smith River, South
Fork Smith River, Newlan Creek, Sheep Creek, Camas Creek, Rock Creek, Eagle Creek,

293 Tenderfoot Creek, Deep Creek, Hound Creek, and Ming Coulee (Figure 2.6). Nineteen of the 68

subwatersheds in the Smith River basin were included: Big Birch Creek, Newlan Creek, Rock
Springs Creek, Camas Creek, Cottonwood Creek, Lower Sheep Creek, Middle Sheep Creek,
Upper Sheep Creek, Moose Creek, Blacktail Creek, Rock Creek, Lower Tenderfoot Creek, Two
Creek, Bear Gulch, Rocky Coulee, Hound Creek, Boston Coulee, and Goodman Coulee (Figure
2.6). The Blacktail Creek subwatershed encompassed the Eagle Creek section used by Montana
Fish, Wildlife & Parks for annual population sampling (Figure 2.6).

300

301 Spawning seasons

302 To determine spawning seasons for rainbow and brown trout, we investigated the detections on tributary antennas of sexually mature fish (Figures 2.8 and 2.9). The spawning 303 304 seasons defined in this study were broader than in past studies so both upstream and downstream 305 portions of spawning migrations could be included. Some fish were not detected moving 306 upstream into tributaries but were detected moving out, and vice versa. Additionally, some 307 spawning activity was observed during late February, further justifying the use of these date 308 ranges. In the upper Missouri River and Sun River basins, spawning seasons for rainbow and 309 brown trout were defined as February 15 to May 31 and September 1 to November 30, 310 respectively (Figure 2.8). For comparison, Grisak et al. 2012 observed radio-tagged rainbow 311 trout spawning from March 3 to May 5 in the Missouri River from 2008 to 2010. In the Smith 312 River basin, spawning seasons for rainbow trout and brown trout were defined as March 1 to 313 June 31 and September 1 to November 30, respectively (Figure 2.9). Mountain whitefish 314 spawning seasons were identical to those defined for brown trout.

315

316 Assumptions

317	Spawning	
318	0	Fish were considered mature if tagging length was over 254 mm (10") to avoid exclusion
319		of young adult fish (particularly precocious males) making potential spawning
320		movements. Numerous young males exhibited milt when collected (269 rainbow trout
321		ranging from 99 mm (3.9") to 373 mm (14.7").
322	0	Fish tagged as juveniles were considered mature the following year unless length at
323		tagging was less than 127 mm (5"). Fish smaller than 127 mm at tagging were considered
324		mature two years later.
325	0	Fish that meet the preceding two criteria and detected on tributary PIT antennas during
326		the spawning season were considered to have spawned.
327	0	Spawning location was defined as the most upstream detection or relocation (including
328		initial tagging) of an individual fish during the spawning season.
329	0	Fish tagged and never redetected were not included in straying and homing rate
330		calculations.
331	Straying and homing	
332	0	If a juvenile fish (less than 254 mm or 10") was tagged in a tributary, the tributary was
333		assumed to be the natal origin of the individual regardless of the time of year tagging
334		took place.
335	0	If an adult fish (greater than 254 mm or 10") was tagged in a tributary during the
336		spawning season, this tributary was assumed to be the natal origin of the individual.
337	0	Several fish were detected in more than one tributary during a single spawning season.
338		Initial detections were considered exploratory movements and the final detection was
339		considered the spawning event.
340		
341	Spawning movements and straying and homing rates	
342		Spawning movements were initially assessed at subwatershed scales based on the
343	resolution of the network of fixed PIT antennas, which included smaller tributaries, such as	
344	Lyons and Wolf creeks (Figure 2.4). However, because the natal origins at this scale were	
345	difficult to determine in some instances, we also assessed spawning movements at a watershed	

346 scale (Figure 2.4). For example, most rainbow trout tagged in Little Prickly Pear Creek were 347 captured in the spring and assigned Little Prickly Pear Creek as their natal stream. However, 348 these fish could have been moving to or from their actual natal origins in the tributaries of Little 349 Prickly Pear Creek (Wolf and Lyons creeks). Analysis at the subwatershed scale could have 350 therefore artificially increased stray rates. In addition, fish tagged in upper subwatersheds that 351 spawned in lower subwatersheds of the same tributary were considered strays. Analysis at the 352 subwatershed scale could have therefore inflated straying rates in the context of fisheries 353 management because fish returns to their natal tributary to spawn are generally considered 354 homing behaviors (Keefer and Caudill 2014). Assessing spawning movements on a watershed 355 scale eliminated these issues for straying and homing analyses but reduced resolution of analysis 356 of spawning effort, so both scales were used. Mainstem spawning was only investigated in the 357 Sun River; results do not include spawning events that occurred in the mainstems of the upper 358 Missouri River (stationary PIT arrays were not installed in the upper Missouri River mainstem) 359 and Smith River.

360 Straying and homing rates were evaluated by tagging location (at watershed and 361 subwatershed scales), species (rainbow and brown trout), and among years. We investigated 362 straying and homing from 2015 to 2018 when the largest numbers of PIT-tagged fish were 363 present; this also allowed the 2014 tagging class to disperse and prevented any overlap with 364 outmigrating individuals. Because numerous fish spawned multiple times, we used numbers and 365 proportions of spawning events in addition to numbers and proportions of individual fish for 366 calculating stray rates. Only fish tagged in their natal streams that spawned were used in the 367 calculations of stray rates. Spawning events made by fish with unknown natal streams (e.g., 368 tagged in the mainstem river) were addressed separately. Natal origin assignment for mountain

- whitefish was not possible because no fish met the criteria listed above. However, we didinvestigate mountain whitefish spawning locations and magnitudes.
- 371 Straying analyses could not differentiate returning spawners from tributary residents. 372 Although fish detected on tributary antennas during spawning seasons were likely entering from 373 the mainstem river, the lack of mainstem antennas made this impossible to verify. We therefore 374 calculated minimum homing rates of fish that were documented outside of their natal stream and 375 made distinct homing movements to spawn. At the subwatershed level, this would include 376 individuals tagged in a natal subwatershed, detected in another subwatershed, and then detected 377 at the natal subwatershed again as a returning spawner. Similarly, lack of mainstem antennas 378 meant that analyses could not identify strays that spawned in the mainstem. However, we could 379 not differentiate mainstem spawners from those with unknown life histories. In summary, we 380 calculated both straying and minimum homing rates. Fish that could not be identified as having 381 strayed or homed would be comprised of tributary residents and fish of unknown life histories. 382 In the Missouri River and Smith River subbasins, tributaries and their respective 383 watersheds and subwatersheds were used as natal locations. Because few fish were tagged in the 384 Sun River and most tagging events occurred outside of spawning seasons, fish tagged in the Sun 385 River subbasin were not assigned natal origins. Moreover, in the Sun River subbasin, fish were 386 only tagged in one tributary, Elk Creek, and in the mainstem Sun River. Therefore, spawning 387 movements were investigated only at the watershed scale. However, discernable spawning movements in the Sun River were not observed for any species; detections during the spawning 388 389 season were reported instead.
- 390
- 391

Results

392

393 <u>Fish detections</u>

394	We redetected 42% (5,036 of 11,936) of PIT-tagged fish in the upper Missouri River
395	basin from 2010 to 2020 (Table 2.5); 181 were redetected only at American White Pelican
396	colonies rather than by PIT arrays or recapture events (see Vivian and Mullen 2018 for
397	comprehensive report). We redetected 37% (2,224 of 5,956) of rainbow trout, 33% (812 of
398	2,495) of brown trout, and 63% (1,785 of 2,846) of mountain whitefish. Of the redetected fish,
399	77% (3,883) were detected by stationary PIT arrays.
400	Twenty-eight percent (988 of 3,572) of fish tagged in the upper Missouri River subbasins
401	were redetected (Table 2.5). Twenty-nine percent (724 of 2,487) of rainbow trout, 20% (128 of
402	633) of brown trout, and 30% (84 of 277) of mountain whitefish were redetected (Table 2.5). Of
403	the 988 total redetected fish, 90% (887) were detected by stationary PIT arrays.
404	Twenty-one percent (156 of 739) of fish tagged in the Sun River subbasin were
405	redetected (Table 2.5). Twenty percent (30 of 153) of rainbow trout, 20% (72 of 353) of brown
406	trout, and 23% (51 of 223) of mountain whitefish were redetected. Of the 156 total redetected
407	fish, 81% (127) were redetected by stationary PIT arrays.
408	Fifty-one percent (3,892 of 7,625) of fish tagged in the Smith River subbasin were
409	redetected (Table 2.5). Forty-four percent (1,470 of 3,323) of rainbow trout, 41% (612 of 1,510)
410	of brown trout, and 70% (1,650 of 2,346) mountain whitefish were redetected. Of the 3,892 total
411	redetected fish, 74% (2,871) were detected on stationary PIT arrays.
412	
413	Natal straying and homing rates

414 Upper Missouri River

415 Rainbow trout

416 A total of 442 (18% of tagged; 61% of redetected) rainbow trout made 601 spawning 417 movements in tributaries of the upper Missouri River from 2014 to 2019 (Table 2.6). Three 418 hundred forty-eight were tagged in their natal streams and accounted for 486 spawning events 419 (Table 2.6). Over the six-year period, 92 fish spawned twice, 25 fish spawned three times, three 420 fish spawned four times, and two fish spawned five times. Seventy-four rainbow trout spawned 421 in at least two consecutive years. Thirty-nine fish had at least a one-year gap between spawning 422 events, six fish had at least a two-year gap, and one fish exhibited a three-year gap between 423 spawning events. The 269 males exhibiting milt when collected ranged from 99 mm (3.9") to 424 373 mm (14.7") and averaged 232 mm (9.2"). Three females were collected with eggs measuring 425 317 mm (12.5"), 361 mm (14.2"), and 381 mm (15").

Seventy percent of rainbow trout spawning events occurred in the Little Prickly Pear
Creek watershed; the remaining 30% was split evenly between the Dearborn River and Sheep
Creek watersheds (Figure 2.10). Wolf Creek was the most used subwatershed (30%), followed
by Lyons Creek (21%), and Little Prickly Pear Creek (18%; Figure 2.11). Distribution of
spawning effort varied among years (Figure 2.12). No rainbow trout tagged in the Missouri River
subbasin were observed spawning in another subbasin. No rainbow trout tagged in another

At the watershed scale, eight (3%) rainbow trout were observed straying from their natal streams 16 times (5%) from 2015 to 2018 (Table 2.7). Fish tagged in the Sheep Creek watershed had the highest stray rate (15%) relative to other watersheds in the Missouri River subbasin (Table 2.8; Figure 2.13). Of all the straying spawning events, 94% strayed to the Dearborn River watershed and 6% occurred in the Little Prickly Pear Creek watershed (Figure 2.14). All

438 spawning events that strayed from the Sheep Creek watershed occurred in the Dearborn River 439 (Table 2.8). Most rainbow trout tagged in the Missouri River spawned in the Little Prickly Pear 440 Creek watershed (Table 2.9). Stray rates were consistent among years (Figure 2.15). 441 Thirteen (5%) rainbow trout were documented outside of their natal watershed and made 442 distinct homing movements back to their natal watershed to spawn 19 times (5%). Minimum 443 homing rates were 6% for fish tagged in the Little Prickly Pear Creek and Sheep Creek 444 watersheds. All rainbow trout that did not return to Sheep Creek spawned in the Dearborn River. 445 One rainbow trout that was tagged in the Dearborn River spawned in the Little Prickly Pear 446 Creek watershed. 447 At the subwatershed scale, 66 (25%) rainbow trout were observed straying from their 448 natal origins 84 times (24%) from 2015 to 2018 (Table 2.10). Rainbow trout tagged in Little 449 Prickly Pear Creek had the highest stray rate (56%) relative to other subwatersheds in the 450 Missouri River subbasin (Table 2.11; Figure 2.16). Except for 1% that spawned in the Dearborn 451 River, all spawning events that strayed from the Little Prickly Pear Creek subwatershed occurred 452 in Lyons (43%) and Wolf creeks (12%). The next highest stray rate was by fish tagged in the 453 Lyons Creek subwatershed (28%; Table 2.11; Figure 2.16). All fish that strayed from the Lyons 454 Creek subwatershed spawned in the Little Prickly Pear Creek subwatershed (Table 2.11). Most 455 spawning events made by rainbow trout tagged in the Missouri River occurred in the Little 456 Prickly Pear Creek subwatershed, but 14% of the fish tagged in the Log Gulch subwatershed 457 spawned in the Dearborn River (Table 2.12). Stray rates remained consistent among years for the 458 Dearborn River, Sheep Creek, and Wolf Creek subwatersheds (Figure 2.15). Stray rates were 459 lower for fish tagged in Lyons Creek in 2015 and Little Prickly Pear Creek in 2017 (Figure 460 2.15).

461 Fifty-seven (21%) rainbow trout were documented outside of their natal subwatershed 462 and made distinct homing movements to spawn 79 times (22%). Minimum homing rates at the 463 subwatershed scale were highest for fish tagged in the Wolf Creek subwatershed (66%). 464 Rainbow trout tagged in the Lyons Creek subwatershed had the lowest minimum homing rate 465 (0%); all nine individuals spawned in the Little Prickly Pear Creek subwatershed. Fish tagged in 466 the Little Prickly Pear Creek subwatershed and Sheep Creek subwatershed had minimum homing 467 rates of 7% and 6%, respectively. 468 469 Brown trout 470 A total of 41 (7% of tagged; 32% of redetected) brown trout made 54 spawning 471 movements in tributaries of the upper Missouri River from 2014 to 2019 (Table 2.6). Fourteen 472 were tagged in their natal streams and accounted for 18 spawning events. Over the six-year 473 period, seven fish spawned twice and two fish spawned four times. All fish that spawned

474 multiple times did so in consecutive years; there were no gaps between spawning events

475 observed. Four brown trout were collected as ripe males that ranged from 300 mm (11.8") to 493

476 mm (19.4") and averaged 432 mm (17.0").

All brown trout spawning occurred in the Little Prickly Pear Creek watershed (Figure
2.17). Within this watershed, most spawning occurred in the Little Prickly Pear Creek
subwatershed (68%), followed by the Wolf Creek (19%) and Lyons Creek (13%) subwatersheds
(Figure 2.17). No brown trout tagged in the Missouri River subbasin were observed spawning in
another subbasin. No brown trout tagged in another subbasin were observed spawning in the
Missouri River subbasin.
483	At the watershed scale, only one (7%) brown trout was observed straying from its natal
484	stream in 2016 (Table 2.7). This individual was tagged in the Sheep Creek watershed and strayed
485	to the Little Prickly Pear Creek watershed (Table 2.8). All brown trout that were tagged in the
486	Missouri River spawned in the Little Prickly Pear Creek watershed (Table 2.9).
487	At the subwatershed scale, 7 (50%) brown trout were observed straying from their natal
488	origins (Table 2.10). Three of the seven brown trout tagged in the Little Prickly Pear Creek
489	subwatershed strayed to Wolf Creek (Table 2.11). One brown trout tagged in Sheep Creek and
490	Wolf Creek strayed to Little Prickly Pear Creek and one brown trout tagged in Lyons Creek
491	strayed to Wolf Creek (Table 2.11). Five of the seven straying events occurred in 2016 (Table
492	2.10).
493	One (6%) brown trout documented outside of its natal watershed made a distinct homing
494	movement to spawn. However, only two total brown trout were documented outside of their
495	natal watershed; the other individual was tagged in the Sheep Creek watershed and spawned in
496	Little Prickly Pear Creek. The other individual was tagged in Little Prickly Pear Creek and
497	returned to spawn there. No brown trout documented outside of their natal subwatershed made
498	distinct homing movements to spawn; all individuals spawned in subwatersheds other than those
499	in which they were tagged (minimum homing rates were 0%).
500	
501	Mountain whitefish

A total of 49 (18% of tagged; 58% of redetected) mountain whitefish made 86 spawning events in the upper Missouri River from 2014 to 2019 (Table 2.6). Over the six-year period, 19 fish spawned twice and eight fish spawned three times. Four fish had a one-year gap between spawning events. All eight fish that spawned three times did so in consecutive years. Twelve males were collected exhibiting milt with tagging lengths ranging from 361 mm (14.2") to 460

507 mm (18.1") and averaging 401 mm (15.8"). One female measuring 442 mm (17.4") was
508 collected with eggs.

 509
 Almost all mountain whitefish spawning occurred in the Dearborn River watershed

510 (98%); 2% occurred in the Little Prickly Pear Creek watershed (Figure 2.18). One mountain

511 whitefish that was tagged in the Deep Creek watershed in the Smith River subbasin spawned in

512 the Dearborn River twice in 2017 and 2018.

All 14 mountain whitefish that were tagged in the Dearborn River watershed returned to spawn (Table 2.9). No mountain whitefish tagged in the Sheep Creek watershed returned to spawn in Sheep Creek; 96% spawned in the Dearborn River watershed and the remaining 4% spawned in Little Prickly Pear Creek (Table 2.9). Of all the mountain whitefish tagged in the Missouri River (N = 230), three were detected spawning and all in the Dearborn River (Table 2.9).

519

506

520 Sun River

521 Rainbow trout

A total of six rainbow trout were redetected seven times during the spawning season in the Sun River subbasin from 2015 to 2018 (Table 2.6). However, only two of these detections were upstream movements to the Dry Creek watershed. All other detections inferred downstream movements. All seven individuals were tagged in Sun River watersheds; no rainbow trout tagged in another subbasin were observed spawning in the Sun River. No rainbow trout tagged in the Sun River subbasin were observed spawning in another subbasin.

529 Brown trout

A total of 30 brown trout were detected 33 times during the spawning season in the Sun River subbasin from 2015 to 2017 (Table 2.6). Most (18) of these detections inferred no movement up or down. Twelve fish were detecting moving downstream, eight of which moved downstream out of Elk Creek. Only two fish were detected moving upstream, one moved into Elk Creek. All 30 individuals were tagged in Sun River watersheds; no brown trout tagged in another subbasin were observed spawning in the Sun River. No brown trout tagged in the Sun River subbasin were observed spawning in another subbasin.

537

538 Mountain whitefish

A total of seven mountain whitefish were detected ten times during the spawning season in the Sun River subbasin from 2015 to 2017 (Table 2.6). Most (eight) detections did not infer movement up or downstream. Only one individual was detected moving upstream and only one individual was detected moving downstream. All seven individuals were tagged in Sun River watersheds; no mountain whitefish tagged in another subbasin were observed spawning in the Sun River. No mountain whitefish tagged in the Sun River subbasin were observed spawning in another subbasin.

546

547 Smith River

548 Rainbow trout

A total of 750 (23% of tagged; 51% of redetected) rainbow trout made 951 spawning movements in tributaries of the Smith River from 2014 to 2019 (Table 2.6). Three hundred ninety-three were tagged in their natal streams accounting for 499 spawning events (Table 2.6). 552 Over the six-year period, 129 fish spawned twice, 28 spawned three times, four fish spawned 553 four times, and one fish spawned five times. One hundred thirty-four spawned at least two 554 consecutive years, 28 fish spawned at least three consecutive years, five fish spawned four 555 consecutive years, and one fish spawned five years in a row.

Most rainbow trout spawning events occurred in the Sheep Creek (78%) and Tenderfoot
Creek (17%) watersheds (Figure 2.19). At the subwatershed scale, 32% of spawning events
occurred in lower Sheep Creek, 24% occurred in Moose Creek, 22% occurred in upper Sheep
Creek, 17% occurred in Tenderfoot Creek, and 3% occurred in Big Birch Creek (Figure 2.20).
No rainbow trout tagged in the Smith River subbasin were observed spawning in another
subbasin. No rainbow trout tagged in another subbasin were observed spawning in the Smith
River subbasin.

At the watershed scale, nine (2%) rainbow trout were observed straying from their natal origins nine (2%) times in 2016 (Table 2.13). All individuals that strayed were tagged in the Sheep Creek watershed. Six of these straying events occurred in the Rock Creek watershed and the remaining three occurred in the Tenderfoot Creek watershed. Fifty-nine percent of rainbow trout tagged in the Smith River mainstem spawned in the Sheep Creek watershed, 38% spawned in the Tenderfoot Creek watershed, 2% spawned in Rock Creek, and the remaining 1% spawned in Hound and Camas creeks.

570 Sixty (15%) rainbow trout were documented outside of their natal watershed and made 571 distinct homing movements to spawn 80 times (17%). Most of these fish were tagged in the 572 Sheep Creek watershed where the minimum homing rate was 16%. Two fish tagged in the 573 Tenderfoot Creek watershed returned to spawn four times. One rainbow trout tagged in the 574 Newlan Creek watershed returned to spawn.

575	At the subwatershed scale, 198 (51%) rainbow trout were observed straying from their
576	natal origins 232 (48%) times from 2015 to 2018 (Table 2.14). All rainbow trout that strayed
577	were either tagged in the upper Sheep Creek (106) or Moose Creek (92) subwatersheds (Table
578	2.14). Rainbow trout tagged in the upper Sheep Creek subwatershed had a 47% stray rate,
579	whereas those tagged in the Moose Creek subwatershed had a 42% stray rate (Table 2.15). Of
580	those tagged in the upper Sheep Creek subwatershed, 25% strayed to Moose Creek and 21%
581	strayed to lower Sheep Creek (Table 2.15). Of those tagged in the Moose Creek subwatershed,
582	21% strayed to upper Sheep Creek and 18% strayed to lower Sheep Creek (Table 2.15). Nearly
583	half (48%) of all spawning events made by rainbow trout tagged in the mainstem Smith River
584	occurred in the lower Sheep Creek subwatershed, a third (33%) occurred in the lower Tenderfoot
585	Creek subwatershed, and 7% occurred in Big Birch Creek (Figure 2.21).
586	Ninety-three (24%) rainbow trout documented outside of their natal subwatershed made
587	distinct homing movements to spawn 103 times (22%). Fish tagged in the Tenderfoot Creek
588	subwatershed had the highest minimum homing rate (100%), but only two fish were tagged there
589	that were documented elsewhere. Fish tagged in the upper Sheep Creek subwatershed had the
590	lowest minimum homing rate (14%). Fish tagged in the Moose Creek subwatershed had a
591	minimum homing rate of 30%. One fish tagged in Newlan Creek that was documented elsewhere
592	returned to spawn there.
593	Stray rates of fish tagged in the upper Sheep Creek and Moose Creek subwatersheds
594	varied among years (Figure 2.22). Stray rates were highest for upper Sheep Creek in 2016 and

595 2018 (Figure 2.22). For fish tagged in the Moose Creek subwatershed, stray rates were highest in
596 2017 and 2018 (Figure 2.22).

598 Brown trout

A total of 157 (10% of tagged; 26% of redetected) brown trout made 199 spawning movements in tributaries of the Smith River from 2014 to 2019 (Table 2.6). Seventy were tagged in their natal streams accounting for 100 spawning events (Table 2.6). Over the six-year period, 29 brown trout spawned twice, five fish spawned three times, and one fish spawned four times. Twenty fish spawned for at least two consecutive years and four fish spawned for three years in a row.

605 Brown trout spawning effort varied among Smith River watersheds and subwatersheds 606 (Figures 2.23 and 2.24). Thirty-eight percent of brown trout spawning events occurred in the 607 Sheep Creek watershed, 18%, occurred in the Rock Creek watershed, 13% occurred in the 608 Hound Creek watershed, 11% occurred in the South Fork Smith River watershed, 10% occurred 609 in the Tenderfoot Creek watershed, and the remaining 10% was split evenly between the Camas 610 Creek and Newlan Creek watersheds (Figure 2.23). At the subwatershed scale, 19% of spawning 611 events occurred in both the upper and lower Sheep Creek subwatersheds, followed closely by 612 Lower Rock Creek (18%; Figure 2.24). Lower Hound Creek, Big Birch Creek, and lower 613 Tenderfoot Creek had 13%, 11%, and 10% of brown trout spawning events, respectively (Figure 614 2.24). The remaining 10% was split evenly between the lower Camas Creek and lower Newlan 615 Creek subwatersheds (Figure 2.24).

At the watershed scale, two (6%) brown trout tagged in the Sheep Creek watershed were observed straying in 2015 (Table 2.13). One of these fish spawned in Rock Creek watershed and one spawned in the Newlan Creek watershed. At the subwatershed scale, 11 (33%) brown trout were observed straying: five in 2015, five in 2016, and one in 2018 (Table 2.14). Nine fish were tagged in upper Sheep Creek and two were tagged in lower Sheep Creek. Of the fish tagged in

621 lower Sheep Creek, one strayed to upper Sheep Creek and one strayed to lower Rock Creek 622 (Table 2.15). Of the fish tagged in upper Sheep Creek, five individuals strayed to lower Sheep 623 Creek and one strayed to lower Newlan Creek (Table 2.15). Spawning locations of brown trout 624 tagged in the mainstem Smith River varied among subwatersheds; most occurred in lower Rock 625 Creek (35%), Big Birch Creek (22%), and lower Tenderfoot Creek (15%; Figure 2.25). 626 Nine (13%) brown trout documented outside of their natal watershed made distinct 627 homing movements to spawn 12 times (12%). Six (9%) brown trout documented outside of their 628 natal subwatershed made distinct homing movements to spawn nine times (9%). Fish tagged in 629 the upper Sheep Creek subwatershed had minimal homing rates of 0%. All fish tagged in Hound 630 Creek, Tenderfoot Creek, and Newlan Creek that were documented elsewhere returned to their 631 natal subwatersheds to spawn. 632 633 Mountain whitefish 634 A total of 734 (31% of tagged; 45% of redetected) mountain whitefish made 1,344 635 spawning movements in Smith River tributaries from 2014 to 2019 (Table 2.6). Three hundred 636 thirty-eight were tagged in their natal streams and accounted for 678 spawning events (Table 637 2.6). Over the six-year period, 192 fish spawned twice, 98 spawned three times, 62 spawned four 638 times, and nine fish spawned five times. Three hundred and three mountain whitefish spawned 639 for at least two consecutive years, 143 spawned for at least three consecutive years, 55 spawned 640 for at least four consecutive years, and one fish spawned five years in a row. 641

Most mountain whitefish spawning occurred in the Sheep Creek (61%) and Tenderfoot Creek watersheds (42%) from 2014 to 2019 (Figure 2.26). The Hound Creek, Rock Creek, and South Fork Smith River watersheds each accounted for 2% of the mountain whitefish spawning 644 events (Figure 2.26). At the subwatershed scale, most spawning occurred in the lower Tenderfoot 645 Creek watershed (32%), followed by lower Sheep Creek (25%), Moose Creek (24%), and upper 646 Sheep Creek (12%; Figure 2.27). The lower Hound Creek, lower Rock Creek, and Big Birch 647 Creek subwatersheds each accounted for 2% of the mountain whitefish spawning effort (Figure 648 2.27). One mountain whitefish that was tagged in the Deep Creek watershed (mainstem Smith 649 River) spawned twice in the Dearborn River in 2017 and 2018 (Figure 2.28). No mountain 650 whitefish tagged in the Sun River or Missouri River subbasins spawned in the Smith River 651 subbasin.

652 At the watershed scale, four (1%) mountain whitefish were observed straying from their 653 natal origins seven (1%) times from 2015 to 2018. Four of these straying events were made by 654 fish tagged (N = 2) in the Sheep Creek watershed and occurred in Tenderfoot Creek. The other 655 three were made by fish tagged (N = 2) in Tenderfoot Creek and occurred in the Sheep Creek 656 watershed. At the subwatershed scale, 85 (25%) mountain whitefish strayed 144 (22%) times. 657 Fish tagged in the upper Sheep Creek subwatershed had the highest stray rate (42%) relative to 658 other subwatersheds in the Smith River subbasin (Table 2.15). All straying events made by these 659 fish occurred in the Moose Creek subwatershed (Table 2.15). Fish tagged in the Moose Creek 660 subwatershed also had a high stray rate (22%); except for 1% that strayed to the lower Sheep 661 Creek subwatershed, all of these straying events occurred in the upper Sheep Creek 662 subwatershed (Table 2.15). Forty-one percent of spawning events made by mountain whitefish 663 tagged in the mainstem Smith River occurred in the lower Tenderfoot Creek subwatershed, 25% 664 occurred in lower Sheep Creek, and 14% occurred in the upper Sheep Creek subwatershed (Figure 2.28). Stray rates were consistent among years (Figure 2.29). 665

666 Thirty-seven (11%) 39 mountain whitefish documented outside of their natal watershed 667 made distinct homing movements to spawn 64 times (10%). Minimum homing rates for fish tagged in the Tenderfoot Creek and Sheep Creek watersheds were 39% and 8%, respectively. 668 669 One hundred fifty-four (46%) mountain whitefish were documented outside of their natal 670 subwatershed and made distinct homing movements to spawn 182 times (27%). Minimum 671 homing rates were highest in the Tenderfoot Creek subwatershed (39%) and lowest in the Moose 672 Creek subwatershed (29%). Fish tagged in the lower Sheep Creek subwatershed had a minimum 673 homing rate of 25%.

674

675 <u>Connectivity among salmonid populations</u>

676 Eight fish were redetected in subbasins different from those in which they were tagged. 677 Two fish (one rainbow trout and one Burbot) were tagged in the upper Missouri River subbasins 678 and redetected in the Smith River subbasin. The rainbow trout was tagged in the Wilson Butte 679 subwatershed in the mainstem Missouri River in the spring of 2016 and redetected in the 680 Goodman Coulee subwatershed in the mainstem Smith River the following spring, eventually 681 spawning in Tenderfoot Creek that same year. The Burbot was tagged in the Wilson Butte 682 subwatershed in the mainstem Missouri River in March of 2016 and redetected three months 683 later in the Goodman Coulee subwatershed in the mainstem Smith River. One rainbow trout was 684 tagged in the Missouri River subbasin (City of Great Falls subwatershed, mainstem river) in 685 autumn of 2015 and redetected twice in the Sun River subbasin (Fourmile Creek watershed, 686 mainstem Sun River) in the summers of 2016 and 2017. Four fish tagged in the Smith River 687 subbasin were redetected in the Missouri River subbasin. Three brown trout, all tagged in the 688 lower Hound Creek subwatershed in July of 2014, were later redetected in the upper Missouri

689 River subbasins; two were redetected in the lower Dearborn River subwatershed later that year 690 and one was redetected in the Sheep Creek subwatershed in 2015. One mountain whitefish was 691 tagged in the Rocky Coulee subwatershed of the mainstem Smith River in 2016 and redetected 692 spawning in the lower Dearborn River subwatershed in the autumns of 2017 and 2018. One 693 mountain whitefish tagged in the Smith River subbasin (Two Creek subwatershed, mainstem 694 Smith River) in the summer of 2014 was redetected in the Sun River subbasin (Fourmile Creek 695 watershed, mainstem Sun River) in December 2015. This same individual returned to the Smith 696 River subbasin the following summer, redetected in the same subwatershed it was tagged in. 697 A total of 107 fish was detected on the Truly Bridge fixed PIT array: eight rainbow trout, 698 three brown trout, 90 mountain whitefish, one Burbot, four White Suckers, and one Longnose 699 Sucker. Of the seven fish that were observed leaving or entering the Smith River subbasin, four 700 (one rainbow trout, two mountain whitefish, and one Burbot) were redetected. All three brown 701 trout that moved from the Smith River subbasin to the Missouri River subbasin were not detected 702 by the Truly Bridge array. 703 704 Discussion 705 706 Stray rates were lower than expected based on work previously done in the upper 707 Missouri River. Rainbow trout radio-tagged in the mainstem Missouri River from 2009 to 2011 708 lacked spawning site fidelity and only 8% of those that spawned in tributaries did so in 709 consecutive years (Grisak et al. 2012b). The longer duration of our monitoring effort may have 710 allowed more alternate-year spawners to return to natal tributaries, thereby reducing stray rates. 711 Indeed, we observed multi-year spawning by all study species in the upper Missouri River and

Smith River subbasins. Minimum homing rates were generally greater than straying rates, but
many fish could not be categorized or were unaccounted for and could have been tributary
residents, mortalities, or undetected.

Our network of PIT antennas may have only been able to monitor specific life histories or fragments thereof. Multiple life histories were observed for all three study species in the Smith River (Ritter 2015; Lance 2019) and radiotelemetry studies across upper Missouri River subbasins provided evidence for variation in spawning migration patterns and distribution (Grisak 2012; Grisak et al. 2012a; Grisak et al. 2012b). Mainstem spawning was not investigated in the upper Missouri River or Smith River subbasins, nor were any fish assigned mainstem natal origins, although we know mainstem spawning takes place (Grisak 2012; Grisak et al. 2012b).

722 Widespread mainstem spawning could explain why such small proportions of spawning 723 fish were observed. Stray rates of the overall population (rather than just those that spawn in 724 tributaries) could therefore be higher than observed because fish with tributary origins that 725 spawned in the mainstem could not be detected. Still, previous work suggested most rainbow 726 trout spawning occurs in tributaries in the upper Missouri River subbasin where our network was 727 installed; Grisak et al. (2012b) reported that only 28% of redds surveyed from 2007 to 2010 were 728 found in the mainstem. However, this was a 64% increase from historical numbers (Grisak et al. 729 2012b), so if this trend continued, mainstem spawning by rainbow trout in the Missouri River 730 could have been even more prevalent during our study. Redd count data from 2015 suggest this 731 was the case as it was estimated 39% of rainbow trout redds were in the mainstem in 2015 (J. A. 732 Mullen, unpublished data).

Minimum homing rates provided more insights into fluvial spawning patterns by
excluding resident fish. However, there remained a large proportion of spawning individuals

735 with known natal origins that could not be categorized as making straying or homing 736 movements. Some fish may have remained tributary residents rather than migrating out to the 737 mainstem. Tributary residence was observed in the Smith River subbasin by rainbow and brown 738 trout and mountain whitefish (Ritter 2015; Lance 2019). Tributary residents could have been 739 interpreted as returning spawners in our straying analyses, thereby lowering straying rates (thus 740 we evaluated minimum homing rates of fish that were documented outside of the natal stream as 741 an alternative). Previous otolith microchemistry and scale growth studies did not include 742 tributary residents because fish were sampled as they outmigrated or in the mainstem Missouri 743 River (Munro 2004; Leathe et al. 2014). Stream residents generally show physical signs of 744 sexual maturity at smaller sizes than their migratory counterparts (Meyer et al. 2003) and we 745 observed numerous ripe male rainbow trout at lengths much smaller than would be expected for 746 migratory individuals.

747 Low proportions of detected spawning individuals may also be a result of low detection 748 rates of PIT arrays and mortality. Detection ranges were generally lowest during spring flows, 749 which also coincided with rainbow trout spawning migrations and contributed to low numbers of 750 outmigrants. In contrast, detection ranges were relatively high during brown trout and mountain 751 whitefish spawning seasons. We would therefore expect proportions of spawning rainbow trout 752 to be lowest relative to total numbers tagged, but this was not observed. Mortality, especially 753 resulting from predation, may partly explain such low proportions, especially in the Smith River; 754 predation rates of American white pelicans on PIT tagged fish in the Smith River ranged from 755 12.3% to 66.1% annually (Vivian and Mullen 2018). However, pelican predation rates on PIT-756 tagged fish in the Missouri and Sun rivers were much lower (Vivian and Mullen 2018).

757 The Dearborn River and Little Prickly Pear Creek and its tributaries are critical to the 758 reproductive success of rainbow trout. If straying among Little Prickly Pear Creek subwatersheds 759 did occur, it was almost always to another tributary within the same watershed (e.g., Wolf Creek, 760 Lyons Creek, or Little Prickly Pear Creek itself). Furthermore, spawning efforts were highest in 761 the Little Prickly Pear Creek watershed for rainbow trout tagged in both tributaries and mainstem 762 alike. Interestingly, spawning location of fish tagged in the mainstem was not necessarily the 763 closest tributary; some rainbow trout tagged in the vicinity (<8.5 rkm) of Little Prickly Pear 764 Creek moved downstream to spawn in the Dearborn River. This same pattern was reported in 765 radio-tagged rainbow trout by Grisak et al. (2012b) and could be indicative of homing behavior 766 considering the energy required to bypass a proximal spawning tributary in favor of one more 767 distant. Similar movements were observed in rainbow trout that strayed from the Dearborn 768 River; rather than spawning in nearby Sheep Creek, strays spawned exclusively in the Little 769 Prickly Pear Creek watershed. Curiously, fish that strayed from Sheep Creek did not show a 770 similar pattern and spawned exclusively in the Dearborn River. 771 Relative to other tributaries in the Missouri River subbasin, Little Prickly Pear Creek and 772 its tributaries are most important for brown trout spawning success. Indeed, all observed brown 773 trout spawning occurred in the Little Prickly Pear Creek watershed, whereas no brown trout were 774 observed making spawning movements in the Dearborn River despite tagging 131 fish in the

tributary itself and 68 in the closest downstream mainstem subwatershed, Dog Creek.

776 Correspondingly, Grisak et al. (2012a) observed no radio-tagged brown trout spawning in the

777 Dearborn River, although some individuals may have spawned at the confluence with the

778 Missouri River. Furthermore, no outmigration from the Dearborn River was observed and very

few juveniles were tagged; Leathe et al. (2014) reported lower numbers of brown troutoutmigrants from the Dearborn River compared to Little Prickly Pear Creek.

781 Proportionally, Sheep Creek has less spawning than other major tributaries to the 782 Missouri River, especially for rainbow and brown trout. Sheep Creek had the lowest proportion 783 of spawning effort relative to other tributaries for all study species, despite tagging 424 rainbow 784 trout and 72 brown trout there (no mountain whitefish were tagged there). Grisak et al. (2012b) 785 also observed the lowest proportion of rainbow trout redds in Sheep Creek. In addition, fish 786 tagged in Sheep Creek had the highest stray rate, suggesting that other tributaries provided 787 preferential spawning habitat regardless of natal origins. Unsurprisingly, Sheep Creek was the 788 only tributary that was never a straying destination of fish with natal origins elsewhere. Early and 789 rapid outmigrations of juvenile trout could have contributed to the high stray rates of natal fish; 790 juvenile dispersal has been associated with propensity to stray in Chinook Salmon (Hamann and

791 Kennedy 2012).

792 The Sun River supports reduced populations of rainbow and brown trout compared to the 793 Missouri and Smith rivers, mainly because of poor habitat conditions (i.e., high water 794 temperatures and low flows during critical times of the year). Whereas trout redds have been 795 documented in the Sun River (J. A. Mullen, personal observation), we did not detect spawning 796 movements made by fish tagged in the Sun River. The lack of spawning movement detections 797 was likely related to the large distance between the PIT antenna arrays, but we did observe some 798 downstream movements during the early portions of spawning seasons. This pattern was similar 799 to a previous study; rather than spawning in the Sun River, Grisak et al. (2012b) observed fish 800 tagged in the lower Sun River moving downstream to spawn in the mainstems and tributaries of 801 the Missouri or Smith rivers.

802 Straying rates and spawning patterns were generally similar for all species in the Smith 803 River as compared to the those observed in the upper Missouri River. Rainbow trout spawning 804 occurred primarily in one tributary watershed encompassing many smaller tributaries. This 805 coupled with the combination of low and high stray rates at the watershed and subwatershed 806 scales suggests that the Sheep Creek watershed in the Smith River is analogous to the Little 807 Prickly Pear Creek watershed in the Missouri River as far as importance to rainbow trout 808 reproduction. Similar to that observed in the Little Prickly Pear Creek watershed in the Missouri 809 River, straying that occurred at the subwatershed level was almost always to other subwatersheds 810 within the same watershed. Unlike that observed in the Missouri River, brown trout spawning 811 effort was widely distributed among tributaries in the Smith River. Regardless, stray rates of 812 brown trout remained low at both watershed and subwatershed scales; homing abilities of brown 813 trout are well-known (Harcup et al. 1984; Armstrong and Herbert 1997). 814 Spawning efforts of mountain whitefish were not widely distributed among tributaries in 815 either subbasin, occurring primarily in the Sheep Creek and Tenderfoot Creek watersheds in the 816 Smith River and Dearborn River in the Missouri River. Consistent with that observed with other 817 species in the study area, stray and return rates of mountain whitefish were low at both spatial 818 scales. Unsurprisingly, mountain whitefish in other systems have exhibited strong homing 819 abilities (Pettit and Wallace 1975; Davies and Thompson 1976; Benjamin et al. 2014). However, 820 the homing abilities we observed were much stronger than expected; homing rates were never 821 lower than 75% at either scale, whereas homing proportions observed in other studies ranged 822 from 37% to 49% (Pettit and Wallace 1975; Benjamin et al. 2014). Again, not including 823 mainstem spawners may have resulted in lowered stray rates; mountain whitefish have been 824 observed spawning in the mainstem Smith River (Lance 2019). Furthermore, in the upper

Missouri River, most mountain whitefish were tagged in either the Dearborn River or the
mainstem Missouri River in subwatersheds near the mouth of the Dearborn River. These were
the few locations where they could reliably be sampled, which also supports their diminished use
of other tributaries for reproduction.

829 Inter-subbasin connectivity is likely higher than we observed. Our network of stationary 830 PIT arrays was designed to monitor interchange between mainstem rivers and tributaries, but not 831 necessarily inter-subbasin movements. Whereas the Sun and Smith rivers were small enough to 832 install mainstem antennas, the width of the Missouri River precluded effective use of PIT 833 telemetry. Furthermore, our PIT array network was sparsest in the area surrounding the 834 confluences of the Sun and Smith rivers with the Missouri River; mainstem antennas in the Sun 835 and Smith rivers were 32 rkm and 14.6 rkm upstream of their mouths, respectively. These 836 antennas (Durocher and Truly Bridge) also exhibited some of the lowest detection ranges 837 observed in the study. Tagged fish that were detected making inter-subbasin movements 838 therefore probably represented even more untagged fish than typically accepted. Radiotelemetry 839 studies unhindered by spatial limitations observed larger proportions of tagged fish making such 840 movements, though sample size was low (N = 43; Grisak et al. 2012b). These studies also 841 monitored the movements of fish tagged in mainstem river habitat, whereas we tagged most fish 842 in tributaries (only 128 rainbow trout were tagged in the mainstem Missouri River compared to 843 2,358 tagged in tributaries).

Despite the low number of fish detected making such movements, some patterns were apparent. This study confirms the inter-basin connectivity of the Missouri River downstream of Cascade with the Smith and Sun rivers that was also observed in past radio telemetry studies. Only 7 rainbow trout and 16 burbot were tagged downstream of Cascade; one rainbow trout and

848 one burbot were detected in the Smith River and one rainbow trout was detected in the Sun 849 River. Although radiotelemetry studies reported only fish tagged in the Missouri and Sun rivers 850 making inter-subbasin movements, we observed more fish moving from the Smith River to the 851 Missouri River. Interestingly, Hound Creek may play an important role in movements between 852 the Smith River and Missouri and Sun rivers. Grisak et al. (2012b) observed two brown trout 853 tagged in the Missouri and Sun rivers spawning in Hound Creek, one of which overwintered 854 there. In contrast, the three brown trout we detected were tagged in Hound Creek and moved to 855 the Dearborn River and Sheep Creek. In addition to spawning areas, Hound Creek may provide 856 an oasis of preferential habitat in the lower prairie region of the Smith River, which is heavily 857 affected by agriculture (Lance 2019).

TABLES

Table 2.1. Number of fish tagged by species and subwatershed in the Missouri River subbasin

from 2014 to 2016. Superscripts represent subwatersheds that include locations of annual

population sampling. Miscellaneous species include Mountain Sucker, Yellow Perch, and

Walleye.

_					Species				
Subwatershed	Rainbow Trout	Brown Trout	Mountain Whitefish	Brook Trout	Burbot	White Sucker	Longnose Sucker	Misc	Total
Tributary									
Dearborn River	390	131	46	-	-	40	46	2	655
Sheep Creek Little Prickly Pear Creek watershed Little Prickly	424	72	-	-	-	2	-	-	498
Pear Creek	521	86	1	-	-	9	2	-	619
Wolf Creek	760	94	-	-	-	-	-	-	853
Lyons Creek	263	114	-	-	-	1	-	-	377
Subtotal	2,358	495	47	-	-	52	48	2	3,002
Mainstem									
City of Great Falls	3	6	7	-	1	2	1	1	21
Dog Creek ¹	66	68	4	-	-	23	1	-	162
Finigan Creek ²	8	4	-	-	-	-	-	-	12
Log Gulch	37	59	114	-	1	-	-	-	211
Prewett Creek	10	-	105	-	-	26	1	1	143
Wilson Butte	4	1	-	-	15	-	1	-	22
Subtotal	128	138	230	-	17	51	4	2	570
Total	2,487	633	277	-	17	103	52	4	3,572

866 867

¹ Craig annual population sampling section.
 ² Cascade annual population sampling section.

Table 2.2. Number of fish tagged by species and subwatershed in the Sun River subbasin from

875 2015 to 2016. Superscripts represent subwatersheds that include locations of annual population

876 sampling. Miscellaneous species include Mountain Sucker, Yellow Perch, and Walleye.

		Species											
	Subwatershed	Rainbow Trout	Brown Trout	Mountain Whitefish	Brook Trout	Burbot	White Sucker	Longnose Sucker	Total				
	Tributary												
	Elk Creek Mainstem	9	125	46	3	-	2	-	142				
	City of Simms ¹	96	128	145	-	-	5	-	374				
	Cutting Shed Coulee	48	100	76	-	-	-	-	223				
	Subtotal	144	228	221	-	-	5	-	597				
~ - -	Total	153	353	223	3	-	8	-	739				
877 878	¹ Simms annual popu	lation sampling s	ection.										
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Table 2.3. Number of fish tagged by species and subwatershed in the Smith River subbasin from

2010 to 2017. Superscripts represent subwatersheds that include locations of annual population

sampling.

-					Species				
Subwatershed	Rainbow Trout	Brown Trout	Mountain Whitefish	Brook Trout	Burbot	White Sucker	Longnose Sucker	Mountain Sucker	Total
Tributary									
Big Birch Creek	8	56	10	11	-	3	-	-	88
Hound Creek	24	367	11	-	-	48	19	-	469
Newlan Creek	1	21	5	33	8	46	-	-	114
Sheep Creek watershed									
Lower Sheep	51	26	120	1	-	9	1	-	208
Middle Sheep	689	77	52	13	-	2	-	-	833
Upper Sheep	284	40	40	4	-	2	-	-	370
Moose Creek	908	6	271	21	-	-	-	-	1,204
Rock Creek	13	68	17	-	-	-	-	-	98
Tenderfoot Creek	483	85	460	94	-	-	-	-	1,122
Subtotal	2,455	706	986	166	8	110	20	-	4,451
Mainstem									
Bear Gulch	42*	48	59	-	-	-	2	-	151
Blacktail Creek ¹	376	172	258	-	6	5	7	-	824
Boston Coulee	18*	38	129	-	-	8	7	-	200
Cottonwood Creek ²	56*	93	211	7	3	6	6	-	381
Rock Springs Creek	38*	178	235	8	2	23	-	-	484
Rocky Coulee	56	47	113	-	-	3	2	-	221
Two Creek	277*	187	356	-	13	12	12	1	858
Subtotal	864	763	1,360	15	24	57	36	-	3,119
Total	3,323	1,510	2,346	192	32	167	56	1	7,625

895

¹ Eagle Creek annual population sampling section.
 * Includes one Westslope Cutthroat Trout. A total of five was tagged in the Smith River subbasin.

904 Table 2.4. Locations, average detection ranges, and detection efficiencies of stationary PIT

Stationary PIT array	GPS coordinates (UTM)	Tag detection distance (inches)	Detection efficiency	Physical location
		Missouri Riv	ver	
Lyons Creek	46.93827, -112.12581	28.5 (6 - 54)	-	Just upstream of confluence with Little Prickly Pear Creek
Wolf Creek	47.00597, -112.08026	29 (6-60)	-	Just upstream of confluence with Little Prickly Pear Creek
Creek	47.02251, -112.02018	17 (2 – 42)		Missouri River Just upstream of confluence with
Dearborn River	47.13017, -111.91295	6.3 (2.5 – 9)	-	Missouri River Just upstream of confluence with
Sheep Creek	47.17681, -111.81165	17.7 (4 – 36) Sun River	-	Missouri River
				Just upstream of Hwy 287 near
HWY 287	47.54768, -112.36674	8.6 (4.5 – 18)	-	Augusta, Montana at rkm 109
Elk Creek	47.51229, -112.33641	30 (4 - 48)	-	rkm 4.5 Unstream of Vaughn, Montana at
Durocher	47.54413, -111.57848	7.2 (3 – 18) Smith Rive	-	rkm 32
			1	Just upstream of confluence with
Big Birch Creek	46.58884, -111.05305	-	0.79	Smith River
Newlan Creek	46 59094 -111 05070	_	0 79	Just upstream of confluence with Smith River
Canvon Ranch	46 60810 -111 06760	-	0.75	rkm 172
Cullyon Runon	10.00010, 111.00700		0.90	Just upstream of confluence with
Benton Creek	46.70542, -111.19305	-	0.79	Smith River Just upstream of confluence with
Camas Creek Smith River at	46.70542, -111.19305	-	0.96	Smith River
Beaver Creek	46.75143, -111.16839	-	1.00	rkm 141 Just upstream of confluence with
Moose Creek	46.80292, -110.91484	-	0.96	Sheep Creek
Upper Sheep Creek Lower Sheep	46.81047, -110.92272	-	0.71	1 rkm downstream of Moose Creek 0.9 rkm upstream of confluence wit
Creek	46.80443, -111.17403	-	0.78	Smith River Just upstream of confluence with
Rock Creek	46.86935, -111.27185	-	0.79	Smith River Just upstream of confluence with
Tenderfoot Creek	46.94185, -111.29404	-	0.98	Smith River
Castle Bar	46.97789, -111.28427	-	0.75	rkm 97 Just downstream of Merganser Ben
Merganser Bend	47.14734, -111.294	-	0.66	boat camp
Hound Creek	47.21261, -111.40371	18.5 (4 - 36)	0.96	rkm 2.4
Truly Bridge	47.35658, -111.44140	7.4(1-18)	0.70	rkm 14.6

9(05	arrays in t	the upper M	lissouri River,	Sun River, and	l Smith	n River subbasins.
		2			,		

Table 2.5. Numbers of fish redetected by stationary PIT arrays, mobile tracking, and physical
recapture events organized by year, species, and subbasin tagged. Totals include numbers of
unique individuals redetected across years; because many individuals were redetected multiple

910 years, these values may not be mathematical sums.

	Species								
Year	Rainbow Trout	Brown Trout	Mountain Whitefish	Brook Trout	Westslope Cutthroat	Burbot	White Sucker	Longnose Sucker	Subtotal
				Missou	ri River				
2014	398	49	21	-	-	-	15	16	499
2015	177	36	62	-	-	-	5	2	282
2016	249	62	48	-	-	1	11	-	372
2017	128	14	29	-	-	-	10	-	181
2018	36	8	8	-	-	-	3	-	55
2019	6	1	-	-	-	-	-	-	7
2020	-	2	-	-	-	-	-	-	2
Subtotal	724	128	84	-	-	-	33	18	988
				Sun I	River				
2015	25	48	33	-	-	-	1	-	107
2016	6	40	25	1	-	-	1	-	73
2017	2	15	6	-	-	-	1	-	24
2018	1	5	4	-	-	-	-	-	10
2019	-	3	2	-	-	-	-	-	5
2020	-	2	-	-	-	-	-	-	2
Subtotal	30	72	51	1	-	-	2	-	156
				Smith	River				
2010	16	7	1	1	-	-	-	-	25
2011	38	13	10	1	-	-	-	-	62
2012	46	15	161	2	-	-	-	-	224
2013	34	5	42	-	-	-	-	-	81
2014	73	47	392	2	-	2	22	1	539
2015	526	134	675	4	-	3	31	5	1,378
2016	608	264	738	11	1	10	22	15	1,669
2017	607	299	912	7	4	9	23	23	1,884
2018	122	48	285	-	1	2	8	4	470
2019	24	6	70	-	-	-	2	-	102
2020	-	1	-	-	-	-	-	-	1
Subtotal	1,470	612	1,650	28	5	15	81	31	3,892
TOTAL	2,224	812	1,785	29	5	16	116	49	5,036

Table 2.6. Numbers of spawning events made by rainbow trout, brown trout, and mountain
whitefish in the upper Missouri River, Sun River, and Smith River subbasins from 2014 to 2019.
Ordinary text indicates the total number of spawning events made whereas italicized text
indicates the number of spawning events made by fish with determined natal origins. *Spawning
movements could not be inferred in the Sun River; detections during spawning seasons are

918 reported instead.

	Year									
Subbasin tagged	2014	2015	2016	2017	2018	2019	Total			
			i	Rainbow Troi	ut					
Upper Missouri River	154 (127)	138 (107)	150 (116)	117 (101)	36 (29)	6 (6)	601 (486)			
Sun River*	-	-	5	1	1	-	7			
Smith River	18 (10)	223 (135)	383 (230)	198 (74)	106 (39)	23 (11)	951 (499)			
	Brown Trout									
Upper Missouri River	2 (0)	18 (6)	22 (8)	8 (2)	3 (2)	1 (0)	54 (18)			
Sun River*	-	18	5	10	-	-	33 (0)			
Smith River	68 (59)	47 (20)	52 (16)	23 (3)	6 (1)	3 (1)	199 (100)			
	Mountain Whitefish									
Upper Missouri River	-	37 (0)	27 (0)	20 (0)	2 (0)-	-	86 (0)			
Sun River*	-	3	2	5	-	-	10(0)			
Smith River	524 (325)	346 (186)	249 (112)	131 (37)	49 (10)	45 (8)	1,344 (678)			

- Table 2.7. Number of straying events by rainbow and brown trout tagged in upper Missouri
- 929 River watersheds from 2015 to 2018. N_{st} represents the total number of observed spawning fish
- 930 that strayed.

					Year		-
	Watershed tagged	N _{st}	2015	2016	2017	2018	Total
					Rainbow T	' rout	
	Dearborn River	1	1	-	-	-	1
	Sheep Creek	6	4	4	4	2	14
	Little Prickly Pear Creek	1	-	1	-	-	1
	Total	8	5	5	4	2	16
					Brown Tr	out	
	Dearborn River	0	-	-	-	-	-
	Sheep Creek	1	-	1	-	-	1
	Little Prickly Pear Creek	0	-	-	-	-	-
021	Total	1	-	1	-	-	1
931							
932							
933							
024							
934							
935							
936							
027							
931							
938							
939							
040							
940							
941							
942							

944	Table 2.8. Percentages of rainbow and brown trout spawning events that returned to or strayed
945	from upper Missouri River watersheds from 2015 to 2018 with known natal origins. N represents
946	the number of observed spawning fish and N_{sp} represents the number of spawning events. Bold
947	values indicate homing percentages. One mountain whitefish tagged in the Smith River drainage
948	was observed spawning in the Dearborn River.

				Ret	turning watershed (%)
	Watershed tagged	Ν	N_{sp}	Dearborn River	Sheep Creek	Little Prickly Pear Creek
					Rainbow Trout	
	Dearborn River	28	35	97	-	3
	Sheep Creek Little Prickly Pear	64	95	15	85	-
	Creek	174	223	1	- Brown Trout	99
	Dearborn River	0	0	-	-	-
	Sheep Creek Little Prickly Pear	1	1	-	-	1.00
	Creek	13	17	-	-	1.00
 950 951 952 953 954 955 956 957 958 						
959						

960	Table 2.9. Percentages of rainbow trout, brown trout, and mountain whitefish spawning events
961	that returned to or strayed from upper Missouri River watersheds from 2015 to 2018 with
962	unknown natal origins. N represents the number of observed spawning fish and N_{sp} represents the
963	number of spawning events. Bold values indicate homing percentages. One mountain whitefish
964	tagged in the Smith River drainage was observed spawning in the Dearborn River.

			Reti	(%)	
Watershed tagged	Ν	N _{sp}	Dearborn River	Sheep Creek	Little Prickly Pear Creek
				Rainbow Trout	
Dearborn River	34	43	93	2	5
Sheep Creek	1	1	-	100	-
Little Prickly Pear Creek	27	27	-	-	100
City of Great Falls (MR)	0	0	-	-	-
Rattlesnake Gulch (MR)	16	22	9	2	89
Stickney Creek (MR)	16	22	5	5	90
				Brown Trout	
Dearborn River	0	0	-	-	-
Sheep Creek	0	0	-	-	-
Little Prickly Pear Creek	1	1	-	-	100
City of Great Falls	0	0	-	-	-
Rattlesnake Gulch (MR)	9	11	-	-	100
Stickney Creek (MR)	14	21	-	-	100
			Λ	Iountain Whitefis	h
Dearborn River	14	25	100	-	-
Sheep Creek	32	53	96	-	4
Little Prickly Pear Creek	0	0	-	-	-
City of Great Falls (MR)	1	1	100	-	-
Rattlesnake Gulch (MR)	2	6	100	-	-
Stickney Creek (MR)	0	0	-	-	-

Table 2.10. Number of straying events by rainbow and brown trout tagged in upper Missouri

971	River subwatersheds. N_{st} represents the total number of observed spawning fish that strayed.

	-		-			
Subwatershed tagged	N_{st}	2015	2016	2017	2018	Tota
				Rainbow T	rout	
Dearborn River	1	1	-	-	-	1
Sheep Creek	6	4	4	4	2	14
Little Prickly Pear Creek	40	14	24	7	3	48
Wolf Creek	10	2	3	3	3	11
Lyons Creek	9	2	3	5	-	10
Total	66	23	34	19	8	84
				Brown Tre	out	
Dearborn River	0	-	-	-	-	-
Sheep Creek	1	-	1	-	-	1
Little Prickly Pear Creek	3	1	1	-	1	3
Wolf Creek	2	-	2	-	-	2
Lyons Creek	1	-	1	-	-	1
Total	7	1	5	-	1	7

983	Table 2.11. Percentages of rainbow and brown trout spawning events that returned to or strayed
984	from upper Missouri River subwatersheds from 2015 to 2018 with known natal origins. N
985	represents the number of observed spawning fish and N_{sp} represents the number of spawning
986	events. Bold values indicate homing proportions. Bold values indicate homing proportions.

			Returning subwatershed (%)							
Subwatershed tagged	vatershed N N _{sp}		Dearborn River	Sheep Creek	Little Prickly Pear Creek	Wolf Creek	Lyons Creek			
					Rainbow Trout					
Dearborn										
River	28	35	97	-	3	-	-			
Sheep Creek Little Prickly	64	95	15	85	-	-	-			
Pear Creek	70	86	1	-	44	12	43			
Wolf Creek	74	101	-	-	6	89	5			
Lyons Creek	30	36	-	-	28	-	72			
-					Brown Trout					
Dearborn										
River	0	0	-	-	-	-	-			
Sheep Creek	1	1	-	-	1.00	-	-			
Little Prickly										
Pear Creek	6	7	-	-	57	43	-			
Wolf Creek	3	3	-	-	33	67	-			
Lyons Creek	4	4	-	-	-	25	75			

995Table 2.12. Percentages of rainbow trout, brown trout, and mountain whitefish spawning events996that returned to or strayed from upper Missouri River subwatersheds from 2015 to 2018 with997unknown natal origins. N represents the number of observed spawning fish and N_{sp} represents the

998 number of spawning events. Bold values indicate homing proportions.

			Returning subwatershed (%)							
Subwatershed tagged	Ν	N _{sp}	Dearborn River	Sheep Creek	Little Prickly Pear Creek	Wolf Creek	Lyons Creek			
					Rainbow Trout					
Dearborn River	34	43	93	2	2	2	-			
Sheep Creek	0	0	-	-	-	-	-			
Little Prickly Pear Creek	0	0	-	-	-	-	-			
Lyons Creek	0	0	-	-	-	-	-			
Wolf Creek	0	0	-	-	-	-	-			
City of Great Falls (MR)	0	0	-	-	-	-	-			
Dog Creek (MR)	16	22	5	5	50	18	22			
Finigan Creek (MR)	1	1	-	100	-	-	-			
Log Gulch (MR)	16	22	14	-	59	18	9			
Prewett Creek (MR)	0	0	-	-	-	-	-			
					Brown Trout					
Dearborn River	0	0	-	-	-	-	-			
Sheep Creek	0	0	-	-	-	-	-			
Little Prickly Pear Creek	0	0	-	-	-	-	-			
Lyons Creek	1	1	-	-	-	-	100			
Wolf Creek	0	0	-	-	-	-	-			
City of Great Falls (MR)	0	0	-	-	-	-	-			
Dog Creek (MR)	14	21	-	-	95	5	-			
Finigan Creek (MR)	0	0	-	-	-	-	-			
Log Gulch (MR)	9	11	-	-	91	9	-			
Prewett Creek (MR)	0	0	-	-	-	-	-			
				Λ	Mountain Whitefish	h				
Dearborn River	14	24	100	-	3	-	-			
Sheep Creek	0	0	-	-	-	-	-			
Little Prickly Pear Creek	0	0	-	-	-	-	-			
Lyons Creek	0	0	-	-	-	-	-			
Wolf Creek	0	0	-	-	-	-	-			
City of Great Falls (MR)	1	1	100	-	-	-	-			
Dog Creek (MR)	0	0	-	-	-	-	-			
Finigan Creek (MR)	0	0	-	-	-	-	-			
Log Gulch (MR)	2	6	100	-	-	-	-			
Prewett Creek (MR)	32	53	96	-	4	-	-			

1003 Table 2.13. Number of straying events by rainbow and brown trout tagged in Smith River

1004 watersheds from 2015 to 2018. N_{st} represents the total number of observed spawning fish that

1005 strayed.

Watershed tagged	N _{st}	2015	2016	2017	2018	Total
			Ì	Rainbow Tro	ut	
Hound Creek	0	-	-	-	-	-
Tenderfoot Creek	0	-	-	-	-	-
Rock Creek	0	-	-	-	-	-
Sheep Creek	9	-	9	-	-	9
Camas Creek	0	-	-	-	-	-
Newlan Creek	0	-	-	-	-	-
South Fork Smith River	0	-	-	-	-	-
Total	9	-	9	-	-	9
				Brown Trou	t	
Hound Creek	0	-	-	-	-	-
Tenderfoot Creek	0	-	-	-	-	-
Rock Creek	0	-	-	-	-	-
Sheep Creek	2	2	-	-	-	2
Camas Creek	0	-	-	-	-	-
Newlan Creek	0	-	-	-	-	-
South Fork Smith River	0	-	-	-	-	-
Total	2	-	-	-	-	2

1013 Table 2.14. Number of straying events by rainbow and brown trout tagged in Smith River

1014 subwatersheds from 2015 to 2018. N_{st} represents the total number of observed spawning fish that

1015 strayed.

			-			
Subwatershed tagged	N_{st}	2015	2016	2017	2018	Total
			j	Rainbow Tro	ut	
Lower Hound Creek	0	-	-	-	-	-
Lower Tenderfoot Creek	0	-	-	-	-	-
Lower Rock Creek	0	-	-	-	-	-
Lower Sheep Creek	0	-	-	-	-	-
Upper Sheep Creek	106	36	56	22	14	128
Moose Creek	92	23	42	24	15	104
Benton Gulch	0	-	-	-	-	-
Lower Camas Creek	0	-	-	-	-	-
Big Birch Creek	0	-	-	-	-	-
Lower Newlan Creek	0	-	-	-	-	-
Total	198	59	98	46	29	232
				Brown Trou	t	
Lower Hound Creek	0	-	-	-	-	-
Lower Tenderfoot Creek	0	-	-	-	-	-
Lower Rock Creek	0	-	-	-	-	-
Lower Sheep Creek	2	1	-	-	1	2
Upper Sheep Creek	9	4	5	-	-	9
Moose Creek	0	-	-	-	-	-
Benton Gulch	0	-	-	-	-	-
Lower Camas Creek	0	-	-	-	-	-
Big Birch Creek	0	-	-	-	-	-
Lower Newlan Creek	0	-	-	-	-	-
Total	11	5	5	-	1	11

1024Table 2.15. Proportions of rainbow and brown trout and mountain whitefish spawning events1025that returned to or strayed from Smith River subwatersheds from 2015 to 2018. N represents the1026number of observed spawning fish and N_{sp} represents the number of spawning events. Bold1027values indicate homing proportions.

				Returning subwatershed (%)								
Subatershed tagged	Ν	Nsp	Lower Hound Creek	Lower Tenderfo ot Creek	Lower Rock Creek	Lower Sheep Creek	Upper Sheep Creek	Moose Creek	Lower Newlan Creek			
					F	Rainbow Tro	ut					
Lower Hound Creek Lower Tenderfoot	1	1	100	-	-	-	-	-	-			
Creek	15	18	-	100	-	-	-	-	-			
Lower Rock Creek	1	1	-	-	-	100	-	-	-			
Lower Sheep Creek	3	3	-	-	-	100	-	-	-			
Upper Sheep Creek	168	214	-	-	1	21	53	25	-			
Moose Creek Lower Newlan	201	250	-	1	2	18	21	58	-			
Creek	1	1	-	-	-	-	-	-	100			
			Brown Trout									
Lower Hound Creek Lower Tenderfoot	14	20	100	-	-	-	-	-	-			
Creek	2	3	-	100	-	-	-	-	-			
Lower Rock Creek	0	0	-	-	-	-	-	-	-			
Lower Sheep Creek	18	25	-	-	4	92	4	-	-			
Upper Sheep Creek	29	42	-	-	-	12	86	-	2			
Moose Creek Lower Newlan	0	0	-	-	-	-	-	-	-			
Creek	7	9	-	-	-	-	-	-	100			
					Мо	untain White	efish					
Lower Hound Creek Lower Tenderfoot	0	0	-	-	-	-	-	-	-			
Creek	22	41	-	93	-	5	2	-	-			
Lower Rock Creek	0	0	-	-	-	-	-	-	-			
Lower Sheep Creek	111	193	-	2	-	94	4	-	-			
Upper Sheep Creek	26	45	-	-	-	-	76	24	-			
Moose Creek Lower Newlan	178	390	-	-	-	1	21	78	-			
Creek	1	1	-	-	-	-	-	-	100			







1033 Figure 2.1. The upper Missouri, Sun, and Smith rivers and their major tributaries. Yellow dots

1034 represent USGS gaging stations used in the study. Black diagonals represent dams or diversions.

1035 Green diamonds represent fixed PIT antenna arrays. Shaded buffers represent areas where fish

- 1036 movement was monitored by fixed PIT antenna arrays, portable PIT antennas, and physical
- 1037 recapture events.
- 1038





1042 Figure 2.2. Operation timelines of stationary PIT arrays in the Smith, Sun, and upper Missouri

1043 River subbasins from 2011 to 2020.





1047 Figure 2.3. Average read ranges of fixed PIT arrays by month from 2015 to 2019.


- 1050 Figure 2.4. The upper Missouri River subbasin watersheds (A) and subwatersheds (B). Light
- 1051 green areas represent watersheds and subwatersheds that were included in the study area. Yellow
- areas represent subwatersheds that encompassed Montana Fish, Wildlife & Parks annual
- 1053 population sampling sections.
- 1054



1056 Figure 2.5. Watersheds of the Sun River subbasin. Light green areas represent watersheds and

1057 that were included in the study area. The yellow area represents the watershed that encompassed

1058 Montana Fish, Wildlife & Parks annual population sampling section at Simms.

1059



- 1062 Figure 2.6. Smith River subbasin watersheds (A) and subwatersheds (B). Light green areas
- 1063 represent watersheds and subwatersheds that were included in the study area. The yellow area
- 1064 represents the subwatershed that encompassed Montana Fish, Wildlife & Parks annual
- 1065 population sampling section near Eagle Creek.



Figure 2.7. Location data of PIT-tagged fish, represented by pink dots, within watersheds (A)and subwatersheds (B) of the upper Missouri River basin.

1069 and











Figure 2.9. Detections of mature (TL > 300 mm) PIT-tagged rainbow trout (A) and brown trout
(B) on all Smith River tributary PIT antennas from 2010 to 2019.



- 1078 Figure 2.10. Proportion of spawning events made by rainbow trout from 2014 to 2019 by
- 1079 watershed in the upper Missouri River subbasin. Proportion is represented by the gray gradient,
- 1080 with darker shades indicating a higher percentage. Light blue areas represent watersheds that
- 1081 were not part of the analysis.



1083 Figure 2.11. Proportion of spawning events made by rainbow trout from 2014 to 2019 by

subwatershed in the upper Missouri River subbasin. Proportion is represented by the gray

1085 gradient, with darker shades indicating a higher percentage. Light blue areas represent

1086 subwatersheds that were not part of the analysis.





1088 Figure 2.12. Distribution of spawning effort by PIT-tagged rainbow trout in tributary

1089 subwatersheds of the upper Missouri River subbasin from 2014 to 2017.



- 1091 Figure 2.13. Stray rates of rainbow trout with known natal origins by watershed tagged in the
- 1092 upper Missouri River subbasin from 2015 to 2018. Stray rate is represented by the gray gradient,
- 1093 with darker shades indicating a higher percentage. Light blue areas represent watersheds that
- 1094 were not part of the analysis.



1096 Figure 2.14. Straying destinations by watershed of rainbow trout that strayed from their natal

1097 streams from 2014 to 2018 in the upper Missouri River subbasin. Proportion is represented by

1098 the gray gradient, with darker shades indicating a higher percentage. Light blue areas represent 1099 watersheds that were not part of the analysis.



Figure 2.15. Stray rates of rainbow trout tagged in upper Missouri River (A) watersheds and (B) subwatersheds. Numbers above bars represent the total number of spawning events made by fish with known noted origins for each watershed and subwatershed for that war

1103 with known natal origins for each watershed and subwatershed for that year.



- 1105
- 1106
- 1107 Figure 2.16. Stray rates of rainbow trout with known natal origins by subwatershed tagged in the
- 1108 upper Missouri River subbasin from 2015 to 2018. Stray rate is represented by the gray gradient,
- 1109 with darker shades indicating a higher percentage.



- 1111 Figure 2.17. Proportion of spawning events made by brown trout from 2014 to 2019 by
- 1112 watershed in the upper Missouri River subbasin. Proportion is represented by the gray gradient,
- 1113 with darker shades indicating a higher percentage. Light blue areas represent watersheds that
- 1114 were not part of the analysis.



- 1116 Figure 2.18. Proportion of spawning events made by mountain whitefish from 2014 to 2019 by
- 1117 subwatershed in the upper Missouri River subbasin. Proportion is represented by the gray
- 1118 gradient, with darker shades indicating a higher percentage. Light blue areas represent
- 1119 watersheds that were not part of the analysis.



- 1121 Figure 2.19. Proportion of spawning events made by rainbow trout from 2014 to 2019 by
- 1122 watershed in the Smith River subbasin. Proportion is represented by the gray gradient, with
- 1123 darker shades indicating a higher percentage. Light blue areas represent watersheds that were not
- 1124 part of the analysis.



- 1126 Figure 2.20. Proportion of spawning events made by rainbow trout from 2014 to 2019 by
- 1127 subwatershed in the Smith River subbasin. Proportion is represented by the gray gradient, with
- darker shades indicating a higher percentage. Light blue areas represent watersheds that were not 1128 part of the analysis.
- 1129



- 1131 Figure 2.21. Proportion of spawning events made by rainbow trout tagged in the mainstem Smith
- 1132 River from 2014 to 2019 by subwatershed in the Smith River subbasin. Proportion is represented
- 1133 by the gray gradient, with darker shades indicating a higher percentage. Light blue areas
- 1134 represent watersheds that were not part of the analysis.





1136 Figure 2.22. Stray rates of rainbow trout tagged in the upper Sheep Creek and Moose Creek

subwatersheds from 2015 to 2018. Numbers above bars represent the total number of spawning

1138 events made by fish with known natal origins for each subwatershed for that year.



- 1139 1140 Figure 2.23. Proportion of spawning events made by brown trout in Smith River watersheds from
- 2014 to 2019. Proportion is represented by the gray gradient, with darker shades indicating a 1141
- 1142 higher percentage. Light blue areas represent watersheds that were not part of the analysis.



- Figure 2.24. Proportion of spawning events made by brown trout in Smith River subwatersheds
- 1145 from 2014 to 2019. Proportion is represented by the gray gradient, with darker shades indicating
- 1146 a higher percentage. Light blue areas represent watersheds that were not part of the analysis.



- Figure 2.25. Proportion of spawning events made by brown trout tagged in the mainstem Smith
- River by subwatershed from 2014 to 2019. Proportion is represented by the gray gradient, with 1149
- darker shades indicating a higher percentage. Light blue areas represent watersheds that were not 1150
- 1151 part of the analysis.



- 1152 1153 Figure 2.26. Proportion of spawning events made by mountain whitefish in Smith River
- watersheds from 2014 to 2019. Proportion is represented by the gray gradient, with darker shades 1154 1155 indicating a higher percentage. Light blue areas represent watersheds that were not part of the
- 1156 analysis.



- Figure 2.27 Proportion of spawning events made by mountain whitefish in Smith River
- subwatersheds from 2014 to 2019. Proportion is represented by the gray gradient, with darker
- 1160 shades indicating a higher percentage. Light blue areas represent watersheds that were not part of 1161 the analysis.



- Figure 2.28. Proportion of spawning events made by mountain whitefish tagged in the mainstem
- 1164 Smith River by subwatershed from 2014 to 2019. Proportion is represented by the gray gradient,
- 1165 with darker shades indicating a higher percentage. Light blue areas represent watersheds that
- 1166 were not part of the analysis.



1167

Figure 2.29. Stray rates of mountain whitefish tagged in the lower Tenderfoot Creek, lower

1169 Sheep Creek, upper Sheep Creek, and Moose Creek subwatersheds from 2015 to 2017. Numbers 1170 above bars represent the total number of spawning events made by fish with known natal origins

1171 for each subwatershed for that year.

1172

1174	CHAPTER THREE
1175	
1176	TIMING OF AND FACTORS INFLUENCING OUTMIGRATION OF RAINBOW AND
1177	BROWN TROUT
1178	
1179	Introduction
1180	
1181	Successful management of fluvial salmonid populations necessitates an understanding of
1182	the requirements of all life history aspects. In addition to spawning and migration patterns, a
1183	critical component of fluvial salmonid life history is outmigration, the early rearing of juvenile
1184	salmonids in natal streams and subsequent migration to larger rivers. Not surprisingly, fluvial
1185	outmigration patterns vary among and within species and populations (Northcote 1997; Munro
1186	2004).
1187	In the upper Missouri River, studies investigating outmigration were conducted as part of
1188	an effort to better understand the resilience of trout populations to the parasite Myxobolus
1189	cerebralis (Leathe et al. 2002; Leathe et al. 2014; Munro 2004). Although two ages of rainbow
1190	trout outmigrate, most individuals spend their first year in their natal streams, Little Prickly Pear
1191	Creek and the Dearborn River, before migrating to the mainstem Missouri River (Leathe et al.
1192	2002; Munro 2004; Leathe et al. 2014). Timing and magnitude of outmigration for age-0 and
1193	age-1 rainbow and brown trout were highly variable and not well-defined, although spring and
1194	autumnal pulses in movement occurred (Leathe et al. 2014).
1195	Variation in outmigration patterns may be in response to biological and environmental
1196	factors (Leathe et al. 2014). Leathe et al. (2014) reported associations with increasing
1197	photoperiod, water temperatures from 7.5 to 12.5 $^{\circ}$ C, and abrupt increases in stream discharge.
1198	However, the variation in timing and magnitude was such that modeling efforts explained no

more than 41% of the outmigration, with the limited amount attributed to a combination ofhighly variable environmental factors and genetic plasticity (Leathe et al. 2014).

1201 Continued efforts to understand the abiotic cues that drive outmigration would provide 1202 insights into the adaptations employed by upper Missouri River trout and enhance management 1203 of their populations. We used PIT telemetry rather than rotary screw traps to monitor the 1204 movements of juvenile rainbow and brown trout in the upper Missouri and Smith rivers. Our 1205 objective was to determine the timing of and factors influencing rainbow and brown trout 1206 outmigration from natal tributaries.

- 1207
- 1208

Methods

1209 Abiotic factors

1210 Temperature and discharge data for the Dearborn, (USGS site 06073500; Figures 3.1 and 1211 3.2), Smith (USGS site 06076690; Figures 3.1 and 3.3), and Sun (USGS site 06085800; Figures 1212 3.1 and 3.4) rivers were collected by USGS gaging stations. Discharge and temperature data 1213 measured in the Dearborn River were used as surrogates to describe hydrologic and thermal 1214 regimes in the Missouri River because of modified temperatures and discharges below Holter 1215 Dam. Discharge data were collected for Little Prickly Pear Creek (USGS site 06071300; Figures 1216 3.1 and 3.5) at the USGS gage station. In addition to collected data, we modeled water 1217 temperatures for the Dearborn River, Little Prickly Pear Creek, Lyons Creek, and Wolf Creek 1218 (see 'Temperature modeling' below). 1219 Daily air temperatures were collected at the Global Historical Climatology Network 1220 (GHCN) weather station in Helena, Montana (Station USR0000MHEL; available at

1221 <u>http://www.ncdc.noaa.gov</u>). Photoperiod was calculated using the National Ocean and

1222 Atmospheric Administration (NOAA) solar calculator, accessed online

1223 (https://www.esrl.noaa.gov/gmd/grad/solcalc). Lunar phase and moon age information was

1224 accessed online from National Aeronautics and Space Administration's scientific visualization

1225 studio (<u>https://svs.gsfc.nasa.gov</u>).

1226

1227 PIT-tagging

1228 A large sampling effort was made in 2014 to tag juvenile rainbow and brown trout in the 1229 major tributaries of the upper Missouri and Smith rivers to investigate outmigration timing and 1230 magnitude. Totals of 1,675 and 288 juvenile rainbow and brown trout were tagged in upper 1231 Missouri River tributaries in 2014, respectively (Table 3.1). Totals of 1,558 and 169 juvenile 1232 rainbow and brown trout were tagged in Smith River tributaries in 2014, respectively (Table 1233 3.2). Tagging was primarily conducted in the Missouri River in the spring, in the spring and 1234 autumn in the Dearborn River, and late summer and autumn in Smith River tributaries. 1235 Fish were collected with boat, barge, and backpack electrofishers, and fyke nets, 1236 anesthesized with Aqui-S 20E (Aqui-S New Zealand Ltd.; 10 to 20 mg/L) or MS-222 (tricaine 1237 methanesulfonate; 50 mg/L), and implanted with HDX PIT tags. Location, species, and total 1238 length (TL) were recorded for each fish at the time of tagging; 20% (2,389 of 11,936) were also 1239 weighed. The date when a fish was collected and tagged was recorded as the first observation for 1240 each individual. PIT tags were surgically implanted into the abdominal cavity through small 1241 incisions made by a small scalpel coated with antiseptic.

1242

1243 Monitoring fish movement

1244	A network of 23 stationary PIT arrays monitored the movements of PIT-tagged fish
1245	throughout the upper Missouri River basin (Table 3.3 and Figure 3.1). Five arrays were installed
1246	in the upper Missouri River subbasins in the spring of 2014, three arrays were installed in the
1247	Sun River subbasin in the spring of 2015, and 15 arrays were installed in the Smith River
1248	subbasin from 2014 to 2016 (Table 3.3 and Figure 3.1). These monitoring stations ran in some
1249	combination from 2010 to 2019 (Figure 3.6). The Dearborn River, Little Prickly Pear Creek,
1250	Truly Bridge, and Hound Creek arrays were damaged by flows in the spring and early summer of
1251	2018. All but Truly Bridge were repaired and reinstalled. Five stations were operated in
1252	Tenderfoot Creek from 2010 to 2014, but only one array installed at the mouth of Tenderfoot
1253	Creek was maintained after 2013 (Table 3.3 and Figure 3.1; Ritter 2015). Age and growth
1254	analyses used data collected prior to 2014 and afterward, but all other analyses were restricted to
1255	data collected after 2013. In general, fixed PIT arrays were installed in locations to monitor
1256	interchange between tributaries and the mainstem within subbasins (Figure 3.1).
1257	Antenna stations consisted of a PIT-tag reader (Oregon RFID, multi-antenna HDX reader
1258	and long-range HDX reader, Portland, Oregon), one to two stream-width antennas, and a tuning
1259	board for each antenna (Oregon RFID, standard remote tuner board and long-range tuner board,
1260	Portland, Oregon). Antenna arrays were powered by 12-V DC supplied by either solar panels or
1261	120-V AC converters. Antennas were placed in areas where fish would unlikely stay for long
1262	periods of time (e.g., riffles and shallow water habitat) to prevent many consecutive detections
1263	and to monitor interchange between mainstem river and tributaries (rather than localized use near
1264	the antennas). All antennas were oriented flat on the bottom (swim over or flat-bed design;
1265	Armstrong et al. 1996) and tuned to best possible vertical read ranges for tags oriented
1266	perpendicularly to the antennas. Average tag detection distances of antennas ranged from 0.03 to

1267 1.50 m (Table 3.3) and varied seasonally (Figure 3.7). Detection efficiencies (Zydlewski 2006)
of PIT arrays installed in the Smith River ranged from 0.66 to 1.00 (Lance 2019). Detection
efficiencies can be used to correct for potential bias associated with variations in detection
efficiencies of stationary PIT arrays (e.g., Lance 2019). We did not account for such bias in this
study; rather, we provided detection efficiencies as a metric for PIT array performance in
addition to tag detection distance.

1273 Mobile PIT arrays were used to actively monitor fish movements and complement the 1274 network of fixed monitoring stations. Mobile tracking was conducted using raft, kayak, and pole-1275 mounted antennas (Hill et al. 2006; McKinstry and Mackinnon 2011); methods are explained in detail by Lance 2019. In the upper Missouri and Sun rivers, mobile tracking by raft and kayak 1276 1277 was conducted in 2015 and 2016 but discontinued thereafter because of low detection range. A 1278 pole-mounted antenna was used in 2016 to scan tributaries and islands of the upper Missouri 1279 River and American white pelican *Pelecanus erythrorhynchus* nesting islands in Canyon Ferry 1280 and Arod Lake (Vivian and Mullen 2018). In the Smith River, all forms of mobile tracking were 1281 used to track fish from 2015 to 2017 (Lance 2019). No mobile tracking was conducted from 1282 2018 onward.

1283

1284

<u>Data analysis</u>

1285

1286 The statistical software programs R (v4.0.2; R Core Team 2019) and SigmaPlot 14 1287 (SigmaPlot 2017) were used for analyzing and plotting trends and comparisons in outmigration 1288 timing and magnitude. Program R was also used for modeling water temperatures. We used geographic information system (GIS) software (QGIS 2021) for spatial analyses and mapconstruction.

1291

1292 <u>Temperature modeling</u>

1293 Because water temperatures were not available for all tributaries for the full duration of 1294 the study, we estimated temperatures using linear regression models where possible, thereby 1295 addressing spatial and temporal gaps in stream water temperature data for the Dearborn River, 1296 Little Prickly Pear Creek, Lyons Creek, and Wolf Creek. We used water temperature data 1297 collected by a network of temperature loggers (Onset Computer Corporation, HOBO 1298 Temperature Data Logger, Bourne, Massachusetts) and the U.S. Geological Survey (USGS) 1299 gaging station at the Dearborn River (USGS site 06073500; USGS 2019). Daily air temperature 1300 measurements collected at the Global Historical Climatology Network (GHCN) weather station 1301 in Helena, Montana (Station USR0000MHEL) were available from the National Climatic Data 1302 Center (http://www.ncdc.noaa.gov). We considered air temperatures collected in Great Falls, 1303 Montana (Stations USW00024143 and USC00243753) as well as near the Sun River, Montana 1304 (Station USC00248021), but water temperatures were most strongly correlated with air 1305 temperatures collected in Helena, Montana based on preliminary investigations. Discharge data 1306 was collected at the Dearborn River (USGS site 06073500; 2019) and Little Prickly Pear Creek 1307 (USGS site 06071300; 2019) USGS gage stations. Data for each climate variable were not 1308 available for all years; rather, data collection ranged in duration (Table 3.4). For example, water 1309 temperature for Lyons Creek was only collected from 2015 to 2017, whereas air temperature was 1310 available from 2000 to 2019 (Table 3.4).

1311 We addressed spatial and temporal gaps in stream water temperature data by estimating 1312 temperatures using linear regression models. Based on available data collected during the study 1313 or previously (Table 3.4), we were able to estimate mean daily water temperatures for the 1314 Dearborn River, Little Prickly Pear Creek, Wolf Creek, and Lyons Creek for the months of 1315 March through November for the entire duration of the study (from 2009 to 2019). We limited 1316 stream temperature modeling to the months of March through November because fish movement 1317 data were not collected outside of that timeframe. In addition, the relationship between air 1318 temperature and water temperature can become nonlinear during the winter months in 1319 waterbodies that experience ice formation (Mohseni and Stefan 1999; Li et al. 2014); using data 1320 only during the open water period therefore improved the predictive power of our linear 1321 regression models.

1322 We considered air temperature, discharge, and mean daily water temperature of nearby 1323 streams as predictors of stream water temperature (Table 3.5). Although models including both 1324 air temperature and discharge yielded better predictive power, we ultimately decided to use only 1325 air temperature as the predictor for Wolf, Lyons, and Little Prickly Pear creeks because of gaps 1326 in discharge and nearby stream temperature data (Table 3.5). Moreover, air temperature 1327 explained 83 - 91% of variation in the data (Figure 3.8); adding discharge only marginally 1328 improved this (Table 3.5; Figure 3.8). However, we decided to use the model including both air 1329 temperature and discharge for estimating mean daily water temperatures of the Dearborn River 1330 because of the completeness of Dearborn River discharge data. Furthermore, we used Dearborn 1331 River mean daily water temperatures for analysis of outmigration in both Sheep Creek (Missouri 1332 River) and the Dearborn River. Air temperature and Dearborn River discharge were not strongly 1333 correlated (Figure 3.9).

1335 <u>Timing of outmigration</u>

We considered rainbow and brown trout under 201 mm (7.9") to be juveniles based on previous work (Leathe et al. 2002; Leathe et al. 2014) and length-frequency histograms created from fish captured during this study. Furthermore, most juvenile trout tagged in upper Missouri River tributaries were likely age-1 fish based on season and length at time of tagging (Leathe et al. 2002). Comparisons made to Leathe et al. 2014 in the discussion are therefore restricted to age-1 trout.

1342 Timing and magnitude of outmigration were assessed using our network of stationary PIT 1343 arrays installed near tributary mouths (Figure 3.1). Numbers of outmigrating juvenile rainbow 1344 and brown trout were quantified by tributary and species. Outmigration evaluation was limited to 1345 2014 and 2015 which ensured fish detections were of outmigrating individuals and not returning 1346 subadults. Fish were deemed to have moved if they were detected at two locations (including 1347 tagging location). In the context of this study, outmigration generally consisted of an individual's 1348 initial tagging location and subsequent downstream detection on a tributary antenna. Tagged fish 1349 were considered outmigrants if they were tagged in a tributary then detected on a tributary mouth 1350 antenna. Date of outmigration was defined as the last detection on a tributary mouth antenna. For 1351 example, if an individual was tagged on March 15, then detected on a tributary antenna 1352 repeatedly from August 1 to August 10, the date of outmigration was considered August 10. For 1353 individuals tagged in Wolf and Lyons creeks, outmigration was defined as entering the mainstem 1354 Missouri River (detection on the Little Prickly Pear Creek antenna), but we also examined timing 1355 and magnitude of movement into Little Prickly Pear Creek. Because we were interested in 1356 outmigration timing, tagged fish that were not detected on a tributary antenna, but were detected

elsewhere beyond the tributary antenna, were not considered outmigrants in the context of this analysis even though outmigration ostensibly occurred. Furthermore, to maintain consistency, these individuals were not used in length-frequency analyses of outmigrants. However, the combined totals of outmigrants and individuals detected elsewhere would provide insights into total magnitude of outmigration effort. We therefore also reported total outmigration, which is a combination of number of outmigrants that meet analysis criteria and number of juveniles that were redetected outside of their tagging tributary.

Graphical representations of timing and magnitude of outmigration were accomplished using frequency-histogram plots and cumulative proportions of outmigrants. For each tributary, we used Welch's two-sample t-tests (if data were normally distributed) or Mann-Whitney rank sum tests (if data were not normally distributed) to assess differences in total length at tagging between PIT-tagged fish that outmigrated in 2014, 2015, and those that did not outmigrate. We used one-way analysis of variance (ANOVA) tests to assess differences in mean total length at tagging of PIT-tagged fish among tributaries.

1371

1372 Abiotic factors influencing outmigration

To make direct comparisons with previous studies in the same system, we conducted statistical analyses that replicated those of Leathe et al. (2014) as closely as possible. We investigated the influence of four categorical predictor variables on numbers of outmigrating rainbow trout from Little Prickly Pear Creek and the Dearborn River and brown trout from Little Prickly Pear Creek. Our predictor variables included discharge, water temperature, photoperiod, and lunar phase. We restricted data from March 1 to November 31 when PIT arrays were most reliable and fish movements were highest. We created five categories representing percent

1380	change in daily discharge: (1) rapidly decreasing (discharge less than 10% of the previous day,
1381	(2) slowly decreasing (discharge less than 1% of the previous day), (3) no change (discharge
1382	within 1% of previous day), (4) slowly increasing (discharge greater than 1% of the previous
1383	day), and (5) rapidly increasing (discharge greater than 10% of the previous day). Daily mean
1384	water temperatures were separated into five ranges: (1) < 7.5 °C, (2) 7.5 to < 10 °C, (3) 10 to <
1385	12.5 °C, (4) 12.5 to < 15 °C, and (5) \geq 15 °C. Moon phases were separated into four categories:
1386	(1) new moon, (2) waxing, (3) full moon, and (4) waning. Photoperiod was divided into three
1387	ranges: (1) before the summer solstice: increasing day length, (2) summer solstice to autumn
1388	equinox: decreasing day length, and (3) after autumn equinox: increasing night length.
1389	For each site × species combination, we constructed global models including all predictor
1390	variables. Therefore, we produced 16 total models for each site \times species combination. Models
1391	were generalized linear models with a Poisson distribution. We used program R package 'AER'
1392	to assess overdispersion in global models (Kleiber et al. 2020). If models were overdispersed, we
1393	used a negative binomial distribution (function 'glm.nb' in the package 'mass'; Ripley et al.
1394	2013). Overdispersion was only detected for rainbow trout outmigrating from Little Prickly Pear
1395	Creek ($P < 0.001$). Despite low variance inflation factors (see paragraph below) and no apparent
1396	multicollinearity, we observed high standard errors for the intercept and temperature variable
1397	modeling rainbow trout outmigration from Little Prickly Pear Creek. Therefore, we removed the
1398	temperature variable from this analysis.
1399	For all global models, we used the 'dredge' function in the package 'MuMIn' to
1400	separately create a set of all possible sub-models and determine the top models for each site \times

1402 Information Criterion to compare models separately for each site × species combination (AIC;

species combination (Bartón 2010). We used an information-theoretic approach using Akaike's
1403 Burnham and Anderson 2004; Mazerolle 2016). We used AIC corrected for small sample sizes 1404 (AIC_C) because number of observations divided by number of parameters was near the suggested 1405 lower limits (i.e., n/K < 40) and AIC and AIC_c converge at larger sample sizes (Anderson and 1406 Burnham 2002; Burnham and Anderson 2004). For model averaging, we included all models 1407 within < 4 AIC_C of the top model and weighted estimates according to AIC weight (AIC_w). We 1408 report parameter estimates (β), standard errors (SE), adjusted SE, and relative importance of each 1409 predictor averaged across top models. We assessed multicollinearity in global and top models for 1410 each site × species combination by calculating variance inflation factors (VIFs) with package 1411 'car' (VIFs ≤ 2 are generally acceptable; Fox et al. 2012). To assess the amount of variation explained by models, we calculated R^2 values for global and top models for each site \times species 1412 1413 combination using the 'rsq' package (Zhang 2018).

1414 Following categorical analyses, we investigated the influence of the same four variables 1415 (discharge, water temperature, photoperiod, and lunar phase) on probability of outmigration, but 1416 the variables were transformed to be continuous. For probability of outmigration, generalized 1417 linear models were fitted with a binomial distribution ("yes" or "no" for outmigration). We 1418 investigated probability of outmigration of rainbow trout from Little Prickly Pear Creek, the 1419 Dearborn River, Sheep Creek, Lyons Creek, and Wolf Creek into the Missouri River and from 1420 Sheep Creek into the Smith River. We also investigated outmigration of brown trout from Little 1421 Prickly Pear Creek into the Missouri River. Preliminary univariate models precluded the inclusion of precipitation or barometric pressure (collected by the Automated Surface Observing 1422 1423 System and accessed online through the Iowa Environmental Mesonet; 1424 https://mesonet.agron.iastate.edu) as predictor variables of outmigration. These variables were 1425 not correlated with probability of outmigration. For each site × species combination, we

1426	constructed global models including all predictor variables. Therefore, similar to the categorical
1427	analyses, 16 total models were produced for each site \times species combination. We investigated
1428	whether including a quadratic form of discharge improved global model fit using likelihood ratio
1429	tests (LRTs; packages 'Imtest'; Hothorn et al. 2019) because we predicted trends in outmigration
1430	could mimic trends in discharge (i.e., increase to peak and decrease). We only included the
1431	quadratic term and removed the normal term to reduce variance inflation factors in global and
1432	top models if the quadratic form of discharge improved model fit. For all combinations, we used
1433	multimodel inference to create sets of all possible sub-models, used an information theoretic
1434	approach to determine the top model, and averaged across top models (all models within < 4
1435	AIC _C of the top model) according to AIC _W .
1436	
1437	Results
1438	
1439	Timing and magnitude of outmigration
1440	Upper Missouri River
1441	Rainbow trout
1442	Four hundred thirty-two fish were redetected from 2014 to 2015; however, only 204 were
1443	detected as outmigrating individuals (147 in 2014 and 57 in 2015, Table 3.1). One hundred
1444	seventy-one individuals ostensibly outmigrated resulting in 375 total outmigrants (Table 3.1).
1445	Rainbow trout ranged in length at tagging from 76 to 201 mm (mean = 135 mm, SD \pm 28.5;
1446	Figure 3.10). Mean tagging length of rainbow trout tagged in Little Prickly Pear Creek was
1447	longer than that of rainbow trout tagged in other upper Missouri River tributaries (mean = 150

1448 mm, P < 0.001; Figure 3.10). Except for those tagged in Lyons Creek, rainbow trout that 1449 outmigrated in 2015 were larger at the time of tagging than in 2014 (P < 0.075; Figure 3.11). 1450 Timing of outmigration of rainbow trout into the Missouri River was highly variable and 1451 differed among tributaries (Figure 3.12). Pulses of outmigration were generally associated with 1452 changes in tributary discharge and occurred both in the spring and autumn, though this second 1453 pulse was usually smaller (Little Prickly Pear Creek was an exception). The bulk of 1454 outmigrations generally occurred prior to baseflow and maximum summer temperatures. Timing 1455 of outmigration out of the Dearborn River was similar to that of Little Prickly Pear Creek but 1456 pulse size was smaller (Figure 3.13). Half of Dearborn River outmigrating fish entered the 1457 Missouri River by the first of July; 90% entered the Missouri by September 25 (Figure 3.14). 1458 Similarly, half of all outmigrating fish tagged in Little Prickly Pear Creek and its tributaries 1459 entered the Missouri River by July 7 and 90% entered the Missouri by September 10 (Figure 1460 3.14). However, pulses of outmigration from Little Prickly Pear Creek were more pronounced 1461 and corresponded with increases in discharge in May and September (Figure 3.13). Another 1462 pulse occurred in July following a modest increase in discharge (Figure 3.13). Outmigration from Sheep Creek occurred earlier; 50% of outmigrating fish entered the mainstem by May 10, 1463 1464 and 90% entered the Missouri River by June 24 (Figure 3.14). Outmigration from Sheep Creek 1465 was characterized by two early pulses in April and June immediately following increases in 1466 discharge and occurring before temperatures reached annual maxima (Figure 3.13). No autumn 1467 outmigration was observed in Sheep Creek.

Outmigration of rainbow trout tagged in Lyons Creek and Wolf Creek into Little Prickly
Pear Creek was similar in pulse timing and size and corresponded with increases in discharge
(Figure 3.15). Half of all fish outmigrating from Lyons Creek and Wolf Creek entered Little

1472 outmigrating from Wolf and Lyons creeks entered Little Prickly Pear Creek on June 24 and June 1473 20, respectively (Figure 3.15). However, remaining fish outmigrated later and more gradually 1474 from Wolf Creek than Lyons Creek (Figure 3.15). Moreover, fish tagged in Wolf Creek 1475 outmigrated from Little Prickly Pear Creek into the Missouri River more gradually than those 1476 that were tagged in Lyons Creek (Figure 3.15). 1477 1478 Brown trout 1479 Although 50 brown trout were redetected, only 38 were detected as outmigrating 1480 individuals (26 in 2014 and 12 in 2015; Table 3.1). Two individuals ostensibly outmigrated 1481 resulting in 40 total outmigrants (Table 3.1). Brown trout length at tagging ranged from 89 to 1482 201 mm (mean = 146 mm, SD \pm 27.6; Figure 3.16). 1483

Prickly Pear Creek on June 12 and June 2, respectively. Seventy-five percent of fish

Outmigration of brown trout began earlier than that of rainbow trout but also appeared to be associated with discharge (Figures 3.17 and 3.18). Timing of outmigration of brown trout could only be determined for fish entering the Missouri River from Little Prickly Pear Creek and its tributaries because too few fish were redetected leaving the Dearborn River and Sheep Creek (Table 3.1). Fifty percent of outmigrating brown trout left Little Prickly Pear Creek and entered the Missouri River by June 21 and 90% entered the Missouri River by October 4 (Figure 3.18). Too few fish were redetected to investigate outmigration of brown trout from Lyons and Wolf creeks into Little Prickly Pear Creek (Table 3.1).

1491

1471

1492 Smith River

1493 Rainbow trout

1494	Six hundred and three juvenile rainbow trout were redetected from 2014 to 2015;
1495	however, only 45 were categorized as outmigrating individuals (11 in 2014 and 34 in 2015;
1496	Table 3.2). Eighty-eight individuals ostensibly outmigrated resulting in 133 total outmigrants
1497	(Table 3.2). Rainbow trout ranged in length at tagging from 46 to 201 mm (mean = 144.5 mm,
1498	SD \pm 32.8; Figure 3.19). Both rainbow and brown trout tagged in Tenderfoot Creek were smaller
1499	than those tagged in other Smith River tributaries (mean = 89 mm and mean = 106 mm,
1500	respectively; $P < 0.001$; Figure 3.20); however, these fish were tagged using 12 mm tags, which
1501	allowed a smaller minimum tagging length.
1502	Because most fish were tagged in late summer and autumn of 2014, more outmigrated in
1503	2015 than in 2014. Too few fish were outmigrated in 2014; the results that follow apply only to
1504	fish that were tagged in 2014 and outmigrated the following year in 2015. Outmigrant rainbow
1505	trout tagged in Moose and Sheep creeks were combined into one group because too few fish
1506	were detected. Too few rainbow and brown trout were detected in tributaries other than Moose
1507	and Sheep creeks to provide reliable outmigrating estimates.
1508	Outmigration of juvenile rainbow trout tagged in Moose and Sheep creeks occurred
1509	primarily in June, July, and October (Figure 3.21). Outmigration pulses corresponded with
1510	increased discharges in June and October as well as increased water temperatures in July (Figure
1511	3.21). Fifty percent of outmigrating rainbow trout entered the Smith River by July 5 and 90%
1512	outmigrated by October 20 (Figure 3.22).
1513	
1514	Brown trout

1515 Thirty-one brown trout were redetected from 2014 to 2015, but only 18 were detected as 1516 outmigrating individuals (6 in 2014 and 12 in 2015; Table 3.2). One individual ostensibly 1517 outmigrated resulting in 19 total outmigrants (Table 3.2). Brown trout length at tagging ranged 1518 from 76 to 201 mm (mean = 149.0 mm, SD \pm 26.1; Figure 3.20). 1519 Outmigration of juvenile brown trout tagged in Hound Creek was characterized by pulses 1520 in early spring and autumn (Figure 3.23). Sixty percent of all outmigrants entered the Smith 1521 River by April 30 and 90% outmigrated by the end of October (Figure 3.23). The flow regime of 1522 the Smith River had little effect on outmigration, but changes in Hound Creek discharge 1523 probably did not coincide with the discharge regime of the Smith River. Too few brown trout 1524 were detected elsewhere to provide reliable analysis. 1525 1526 Diel timing 1527 Timing of outmigrations in the Missouri and Smith rivers occurred throughout the day 1528 but peaked from just after sunset (2000) to midnight and was lowest during the afternoon and 1529 early evening (1200 to 1900; Figure 3.24). There were no discernible differences in the diel 1530 timing of outmigration among tributaries or species (Figure 3.25). 1531 1532 Abiotic factors influencing outmigration 1533 Upper Missouri River 1534 Rainbow trout 1535 The top categorical models for number of rainbow trout outmigrating from Little Prickly 1536 Pear Creek included photoperiod and lunar phase; however, categorical models explained only 2% of the variation in the data ($R^2 = 0.02$; Table 3.6). Photoperiod category 3 (increasing night 1537

1539 trout (P = 0.003). Other factors were not statistically significant. The top continuous model

1538

1540 included discharge, photoperiod, and temperature (Table 3.7). Continuous models explained 14%

length) was the most influential of all predictor variables on the number of outmigrant rainbow

1541 of the variation in the data (Table 3.7). Increasing photoperiod was strongly associated with 1542 probability of outmigration and included in seven models (p = 0.007; Figure 3.26). Discharge 1543 was included in four models whereas temperature and lunar phase were only included in three. 1544 The top categorical model for number of rainbow trout outmigrating from the Dearborn 1545 River consisted of the intercept only, but each factor was included in other top models. No 1546 variables were correlated with probability of outmigration. The top continuous model included 1547 discharge and temperature, but neither were associated with probability of outmigration. 1548 Furthermore, this model explained only 3% of the variation in the data (Table 3.7). 1549 In addition to Little Prickly Pear Creek and the Dearborn River, we also investigated 1550 continuous models for rainbow trout outmigrating from Sheep, Lyons, and Wolf creeks. The top 1551 model for outmigrants in Sheep Creek included both temperature and photoperiod; increasing 1552 photoperiod was associated with increased probability of outmigration (P = 0.015; Figure 3.26). 1553 Top models for Lyons Creek included discharge and photoperiod, and there was marginal 1554 evidence (P = 0.081) that increasing photoperiod was associated with outmigration (Table 3.7). 1555 The top model for Wolf Creek included only photoperiod, and similar to Lyons Creek, 1556 photoperiod was positively associated with probability of outmigration (P = 0.008; Figure 3.27). 1557 Only 4% of the variation in data was explained by models for Lyons and Wolf creek outmigrants 1558 and only 6% was explained by models for Sheep Creek.

1559

1560 Brown trout

1561 The top categorical models for number of brown trout outmigrating from Little Prickly 1562 Pear Creek included photoperiod and lunar phase, but neither were influential on predicting the 1563 number of outmigrants (Table 3.6). Categorical models explained little of the variation in the

data ($R^2 = 0.01$; Table 3.6). The top continuous model included only photoperiod (Table 3.7); no 1564 1565 variables were associated with the probability of brown trout outmigration. Similar to categorical 1566 models, the top continuous model explained little variation in data (<1%; Table 3.7). Too few 1567 brown trout were observed outmigrating from other tributaries to provide reliable estimates 1568 (Table 3.1). 1569 1570 Smith River 1571 Rainbow trout 1572 We developed continuous models for outmigration of rainbow trout from only one Smith 1573 River tributary, Sheep Creek. The top model included temperature and discharge; temperature 1574 was included in all seven top models, whereas discharge was included in four. Increasing 1575 temperature was associated with increased probability of outmigration (P = 0.018; Figure 3.27). The top model explained 11% of the variation in data. 1576 1577 1578 Discussion 1579 1580 Patterns in outmigration varied among species and locations and were influenced by a 1581 number of different factors. Our analysis implicated some environmental factors as influential on 1582 outmigration, but primary drivers in some systems were unclear. Bimodal pulses in outmigration, 1583 generally consisting of a large pulse in spring or summer and another smaller pulse in autumn, 1584 occurred in every tributary except for Sheep Creek (Missouri River). In addition to reporting 1585 similar outmigration timing, Leathe et al. (2014) also observed bimodal pulses in fish 1586 outmigrations from Little Prickly Pear Creek and the Dearborn River wherein the autumnal pulse 1587 was smaller. However, unlike Leathe et al. (2014), the second pulse occurred immediately 1588 following a sudden and unseasonably large increase in discharge in our study. The unseasonable 1589 pulse might explain the magnitude of autumnal outmigration observed in Little Prickly Pear 1590 Creek. Cumulative proportion analyses illustrated that most outmigration occurred before 1591 discharges reached base flows and temperatures reached annual maximums. Therefore, it is 1592 possible that most outmigrants leave tributaries before hydrologic and thermal conditions 1593 become unfavorable. This was also observed by Leathe et al. (2014), especially for age-1 fish. 1594 As fish grow, demand for energy and space increase and resource availability in tributaries 1595 becomes less favorable (Chapman 1966). Mainstem river habitat may have been more productive 1596 for rearing. The early, rapid outmigration that occurs in Sheep Creek (Missouri River) may 1597 indicate that this site has the least favorable conditions for juvenile trout relative to other 1598 tributaries in the study.

1599 Results from our models with continuous variables aligned with the findings of Leathe et 1600 al. (2014) more than our categorical models; however, none of the variables considered 1601 explained much variation. Contrary to our categorical analysis results, models with continuous 1602 variables identified increasing photoperiod as the most influential environmental variable 1603 affecting outmigration. Although photoperiod was the most prominent factor in categorical 1604 models and was positively associated with outmigration in three of our comparisons, increasing 1605 night length was identified as most influential. This could be related to the unseasonable pulse in 1606 discharge and concomitant pulse in outmigration we observed in autumn when night length 1607 increases.

1608 It is difficult to determine how much temperature and discharge influenced outmigration 1609 based on our models. Leathe et al. (2014) reported a temperature preference of 7.5–12.5°C for

outmigration, which is consistent with numerous other salmonid outmigration studies (Osterdahl 1611 1969; Jonsson and Ruud-hansen 1985; Pavlov et al. 2008), but we did not find strong influences 1612 of temperature. Temperature was only influential for rainbow trout migrating from Sheep Creek 1613 into the Smith River and outmigration increased when temperatures were 15–20°C, which is 1614 much higher than reported elsewhere. Cumulative proportion graphs showed outmigration 1615 concomitant with changes in discharge and temperature, but influences of either on models were 1616 not consistent among species and tributaries.

Our interpretation of timing of outmigration probably did not influence the effectiveness of our models. Our analysis defined the last detection on these antennas as the outmigration date, but some individuals were detected multiple times over periods of days or weeks on tributary antennas. In contrast, some other studies employing PIT technology to investigate outmigration timing used the initial detection (e.g., Glaid 2017). We therefore performed preliminary analyses investigating the effect of outmigration date (initial detection vs. last detection) on model strength and determined that last detection provided the most reliable analysis.

1624 Our analysis of outmigration, particularly those with categorical variables, were not 1625 particularly effective in determining factors influencing outmigration, underscoring the great 1626 temporal and spatial variability in environmental influences on outmigration. Such difficulties in 1627 identifying relationships between salmonid outmigration and abiotic cues were echoed in Leathe 1628 et al. (2014) and in other systems using similar methodologies (Homel and Budy 2008; Pavlov et 1629 al. 2008). It is likely that all the variables we included influence outmigration, but levels of 1630 influence differ from site to site and even seasonally. For example, emigration of juvenile Bull 1631 Trout in the Grande Ronde drainage, Oregon, were correlated with peaks in discharge in spring 1632 but falling temperatures in autumn (Bellerud et al. 1997). A PIT telemetry study on Bull Trout

1633 outmigration in the Walla Walla River, Oregon, found that seasonal modeling revealed 1634 influential factors previously obscured by variability across seasons (Homel and Budy 2008). 1635 Including model interactions between environmental variables and seasons to investigate this 1636 question would require larger numbers of observations of outmigration than included in this 1637 study. Therefore, sub-setting data and modelling within years may be a stronger approach to 1638 detect annual or seasonal differences in outmigration cues. Regardless of the individual variable 1639 or combination of variables associated with outmigration, this study and Leathe et al. (2014) both 1640 documented bimodal pulses of outmigrations in spring and fall that in some cases appeared 1641 related to increases in discharge.

1642 Factors leading to differences among outmigrant lengths at tagging were unclear. The 1643 larger size of rainbow trout outmigrants in Little Prickly Pear Creek may indicate a productive 1644 rearing environment that promotes rapid growth. However, it is also possible that some rainbow 1645 trout in this watershed spend their first year in the tributaries of Lyons and Wolf creeks, 1646 outmigrating to Little Prickly Pear Creek as age-1 fish before outmigrating to the Missouri River. 1647 We are uncertain why more fish with larger size at tagging outmigrated in 2015. It is possible 1648 these fish outmigrated in their second year; however, migration checks in the second annulus of 1649 scale growth patterns suggested a low proportion (1.5%) of rainbow trout exhibit this strategy in 1650 the Missouri River (Munro 2004). It is more likely that these fish outmigrated in 2014 but were 1651 not detected and were in fact returning as subadults or spawners. Numerous (N = 87) male 1652 rainbow trout with tagging lengths less than 254 mm (10") were observed with milt. 1653 Furthermore, tag detection ranges of fixed PIT arrays were generally lowest during spring 1654 discharges, which often coincided with outmigration pulses.

1655 The generally low sample sizes observed in our study could be attributed to a lack of 1656 detections by fixed PIT arrays, which were necessary to classify individual outmigrants. Our data 1657 set of known outmigrants might have been larger had PIT tag detection ranges been higher 1658 during periods of outmigration. We likely underestimated outmigration as detection rates 1659 decrease with increased water volume, velocities, and depths (e.g., Zydlewski et al. 2006). Read 1660 ranges almost always dropped following spring discharges, frequently to annual lows. Increases 1661 in water velocities can rearrange antenna shapes and negatively affect tuning (Zydlewski et al. 1662 2006). Indeed, our antennas frequently required repair and retuning following spring discharges. 1663 Nevertheless, we felt that our sample sizes were high enough to proceed with analyses as they 1664 were consistent with other PIT telemetry studies of outmigration with similar numbers of fish 1665 tagged and issues encountered (Homel and Budy 2008).

1666 Low outmigrant sample sizes might also be a result of a resident life history pattern that 1667 was influenced by tagging location. Total numbers of outmigrants comprised relatively low 1668 proportions of total numbers of juveniles tagged, but total numbers of juvenile fish redetected on 1669 all antennas were high in comparison. Rather than moving past tributary antennas undetected, 1670 many fish probably remained in their natal streams and became tributary residents. Location may 1671 have biased tagging efforts toward resident fish. For example, most fish in the Sheep Creek 1672 watershed in the Smith River were tagged in the upper reaches; had more fish been tagged closer 1673 to the confluence, more outmigrants may have been observed.

1674 Our attempt to replicate the analyses of Leathe et al. (2014) may have been limited by our 1675 methodology and subsequent sample size. Rotary screw traps employed by Leathe et al. (2014), 1676 though time intensive, captured thousands of fish per tributary per sampling season. PIT 1677 telemetry allowed us to passively and continuously monitor tagged fish but was limited in

- 1678 numbers of redetected fish. Our highest sample size was 95 for rainbow trout outmigrating from
- 1679 Little Prickly Pear Creek. Even so, continuous models may be more appropriate for outmigration
- 1680 analyses because trends in environmental variables are often continuous in nature. Additionally,
- 1681 results from continuous models may be more informative to fisheries managers making
- 1682 predictions across a wide spectrum of environmental variables in the field.

TABLES

1684

- 1685 Table 3.1. Number and proportions of juvenile rainbow trout and brown trout (< 201 mm)
- 1686 tagged, redetected, and outmigrated in upper Missouri River tributaries from 2014 to 2015. All
- 1687 fish tagged in 2014. Outmigration is defined as the last detection on the tributary mouth antenna;
- 1688 for fish tagged in Wolf Creek and Lyons Creek, outmigration is defined as the last detection on
- 1689 the Little Prickly Pear Creek antenna.

Tributary	Tributary Number Number/proportion Number/proportion tagged redetected outmigrated 2014			Number/proportion outmigrated 2015	Total outmigrants		
	Rainbow Trout						
Dearborn River	257	52 (0.20)	31 (0.12)	11 (0.04)	44 (0.17)		
Sheep Creek	318	66 (0.21)	21 (0.07)	16 (0.05)	39 (0.12)		
Little Prickly Pear Creek watershed							
Little Prickly							
Pear Creek	280	90 (0.32)	39 (0.14)	7 (0.03)	60 (0.21)		
Wolf Creek	624	153 (0.25)	38 (0.06)	16 (0.03)	57 (0.09)		
Lyons Creek	196	71 (0.36)	18 (0.09)	7 (0.04)	29 (0.15)		
Subtotal	1,100	314 (0.29)	95 (0.09)	30 (0.03)	146 (0.13)		
Total	1,675	432 (0.26)	147 (0.09) 57 (0.03)		375 (0.22)		
			Brown Trout				
Dearborn River	28	1 (0.04)	0	0	0		
Sheep Creek	51	5 (0.10)	2 (0.04)	0	3 (0.06)		
Little Prickly Pear Creek watershed							
Little Prickly							
Pear Creek	66	23 (0.35)	15 (0.23)	1 (0.02)	16 (0.24)		
Wolf Creek	70	11 (0.16)	1 (0.01)	3 (0.04)	5 (0.07)		
Lyons Creek	73	18 (0.25)	8 (0.11)	8 (0.11)	16 (0.22)		
Subtotal	209	52 (0.25)	24 (0.11)	12 (0.06)	35 (0.17)		
Total	288	58 (0.20)	26 (0.09)	12 (0.04)	40 (0.14)		

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Table 3.2. Number and proportions of juvenile rainbow trout and brown trout (< 201 mm)
tagged, redetected, and outmigrated in Smith River tributaries from 2014 to 2015. All fish were
tagged in 2014. Outmigration is defined as the last detection on the tributary mouth antenna; for
fish tagged in Moose Creek, outmigration is defined as the last detection on the Lower Sheep
Creek antenna.

Tributary	Number tagged	Number/proportion redetected	Number/proportion outmigrated 2014	Number/proportion outmigrated 2015	Total outmigrants
		R	ainbow Trout		
Hound Creek	13	2 (0.15)	1 (0.08)	1 (0.08)	2 (0.15)
Tenderfoot Creek	135	17 (0.13)	8 (0.06)	3 (0.02)	19 (0.14)
Sheep Creek watershed					
Sheep Creek	651	244 (0.37)	1 (0.002)	22 (0.03)	52 (0.08)
Moose Creek	759	340 (0.45)	0	8 (0.01)	60 (0.08)
Subtotal	1,410	584 (0.41)	1 (0.001)	30 (0.02)	112 (0.08)
Total	1,558	603 (0.39)	11 (0.01)	34 (0.02)	133 (0.09)
		1	Brown Trout		
Hound Creek	121	18 (0.15)	2 (0.02)	11 (0.09)	16 (0.13)
Tenderfoot Creek	17	3 (0.18)	1 (0.06)	0	1 (0.06)
Sheep Creek watershed					
Sheep Creek	29	8 (0.28)	0	1 (0.03)	2 (0.07)
Moose Creek	2	2 (1.00)	0	0	0
Subtotal	31	10 (0.32)	0	1 (0.03)	2 (0.06)
Total	169	31 (0.18)	6 (0.04)	12 (0.07)	19 (0.11)
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1703					
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2,00					
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- 1709 Table 3.3. Locations, average detection ranges (minima and maxima in parentheses), and
- 1710 detection efficiencies of stationary PIT arrays in the upper Missouri River, Sun River, and Smith
- 1711 River subbasins.

Stationary PIT array	GPS coordinates (UTM)	Tag detection distance (inches)	Detection efficiency	Physical location
		Missouri Riv	ver	
Lyons Creek	46.93827, -112.12581	28.5 (6 - 54)	-	Just upstream of confluence with Little Prickly Pear Creek Just upstream of confluence with
Wolf Creek Little Prickly Pear	47.00597, -112.08026	29 (6 - 60)	-	Little Prickly Pear Creek Just upstream of confluence with
Creek	47.02251, -112.02018	17 (2 – 42)		Missouri River Just upstream of confluence with
Dearborn River	47.13017, -111.91295	6.3 (2.5 – 9)	-	Missouri River Just upstream of confluence with
Sheep Creek	47.17681, -111.81165	17.7 (4 – 36) Sun River	-	Missouri River
				Just upstream of Hwy 287 near
HWY 287	47.54768, -112.36674	8.6 (4.5 – 18)	-	Augusta, Montana at rkm 109
Elk Creek	47.51229, -112.33641	30 (4 - 48)	-	rkm 4.5 Unstream of Vaughn, Montana at
Durocher	47.54413, -111.57848	7.2 (3 – 18)	-	rkm 32
		Smith Rive	r	
Big Birch Creek	46 58884 -111 05305	_	0 79	Just upstream of confluence with Smith River
Big Birch Cleek	10.50001, 111.05505		0.19	Just upstream of confluence with
Newlan Creek	46.59094, -111.05070	-	0.79	Smith River
Canyon Ranch	46.60810, -111.06760	-	0.96	rkm 172
				Just upstream of confluence with
Benton Creek	46.70542, -111.19305	-	0.79	Smith River
Camas Creek	46 70542 -111 19305	_	0.96	Smith River
Smith River at	10.705 12, 111.19505		0.90	
Beaver Creek	46.75143, -111.16839	-	1.00	rkm 141
Moore Creek	16 20202 110 01/2/		0.06	Just upstream of confluence with
Moose Creek	40.80292, -110.91484	-	0.96	1 rkm downstream of Moose Creek
Lower Sheep	40.01047, -110.92272	-	0.71	0.9 rkm upstream of confluence with
Creek	46.80443, -111.17403	-	0.78	Smith River
				Just upstream of confluence with
Rock Creek	46.86935, -111.27185	-	0.79	Smith River
Tenderfoot Creek	46.94185, -111.29404	-	0.98	Smith River
Castle Bar	46.97789, -111.28427	-	0.75	rkm 97
			0.55	Just downstream of Merganser Bend
Merganser Bend	47.14734, -111.294	-	0.66	boat camp
Hound Creek	47.21261, -111.40371	18.5(4-36)	0.96	rkm 2.4
I ruly Bridge	47.33638, -111.44140	/.4 (1 – 18)	0.70	rkm 14.6

1713 Table 3.4. Details of climate data used for estimating stream temperatures. No data was collected

1714 for Sheep Creek (Missouri River).

Location	Measurement(s)	Method	Years collected
Wolf Creek	Stream temperature	Temperature logger	2015-2017
Lyons Creek	Stream temperature	Temperature logger	2015-2017
	Stream temperature	Temperature logger	1997-2006
Little Prickly Pear Creek	Discharge	USGS gage station	1997-2019
	Stream temperature	USGS gage station	2000-2019
Dearborn River	Discharge	USGS gage station	2000-2019
Helena, Montana	Air temperature	GHCN weather station	2000-2019

1716 Table 3.5. Linear models for predicting mean daily stream temperatures in Little Prickly Pear

1717 Creek, Lyons Creek, Wolf Creek, and the Dearborn River, Montana, USA. Data for Little

1718 Prickly Pear Creek model is from 2000 to 2003 and 2005 to 2006. Data for the Dearborn River

1719 model was collected from 2000 to 2019. Models used are displayed in bold text.

Predictor(s)	Р	r^2	RMSE
Lyons Creek model			
Air temperature	<i>P</i> < 0.001	0.836	1.485
Little Prickly Pear Creek discharge	P < 0.001	0.105	3.416
Air temperature + Little Prickly Pear Creek discharge	P < 0.001	0.862	1.345
Wolf Creek model			
Air temperature	<i>P</i> < 0.001	0.892	1.285
Little Prickly Pear Creek discharge	P < 0.001	0.102	3.608
Air temperature + Little Prickly Pear Creek discharge	<i>P</i> < 0.001	0.915	1.114
Little Prickly Pear Creek m	odel		
Dearborn River water temperature	<i>P</i> < 0.001	0.960	1.038
Air temperature	<i>P</i> < 0.001	0.914	1.566
Little Prickly Pear Creek discharge	P < 0.01	0.007	5.232
Dearborn River water temperature + discharge	<i>P</i> < 0.001	0.964	0.977
Air temperature + Little Prickly Pear Creek discharge	<i>P</i> < 0.001	0.918	1.530
Dearborn River model			
Air temperature	<i>P</i> < 0.001	0.855	2.043
Dearborn River discharge	P < 0.001	0.048	5.210
Air temperature + Dearborn River discharge	<i>P</i> < 0.001	0.890	1.782

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1724	Table 3.6. The top-ranked categorical models (of 16 total models each per site \times species
1725	combination) for number of outmigrants of rainbow and brown trout tagged in Little Prickly Pear
1726	Creek and the Dearborn River. Models are sorted by corrected Akaike information criterion
1727	(AIC _C) with log likelihood ('LogLik'), difference in AIC_C from the best supported model
1728	(ΔAIC_C), and model weights (AIC _W). Models within < 4 AIC _C of the top model were included in
1729	the top model set and multimodel inference. Each model includes an intercept term and
1730	'intercept only' denotes when no other predictors were included. Each predictor variable besides
1731	the intercept is categorical and includes up to five separate categories. Variance inflation factors
1732	are included for top models ('VIF') and for global models ('VIF _G '). R-squared values are also
1733	included for top models (' R^2 ') and global models (' R^2_G '). Within VIF, 'ND' indicates that VIFs
1734	could not be calculated because < 2 variables were included in that top model.

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Species	Num.	Model	df	LogLik	AIC _C	ΔAIC_{C}	AICw	VIF	\mathbb{R}^2	VIF _G	R^2_G
	Little Prickly Pear Creek										
Rainbow Trout	1	Photoperiod	4	-189.94	388.04	0.00	0.88	ND	0.02	< 1.9	0.08
	2	Lunar phase + Photoperiod	7	-188.78	391.97	3.94	0.12				
Brown Trout	1	Photoperiod	3	-62.05	130.19	0.00	0.47	ND	0.01	< 2.1	0.03
	2	(Intercept only)	1	-64.32	130.66	0.46	0.37				
	3	Lunar phase + Photoperiod	6	-60.66	133.64	3.45	0.08				
	4	Lunar phase	4	-62.91	133.98	3.79	0.07				
			Dearb	orn River							
Rainbow Trout	1	(Intercept only)	1	-102.13	206.28	0.00	0.45	ND	0.00	< 3.4	0.07
	2	Photoperiod	3	-100.93	207.95	1.67	0.20				
	3	Temperature	5	-99.10	208.42	2.14	0.16				
	4	Discharge	5	-99.46	209.14	2.86	0.11				
	5	Lunar phase	4	-100.74	209.63	3.35	0.09				
736											

1736 1737

1739	Table 3.7. Top-ranked continuous models for probability of outmigration of rainbow or brown
1740	trout from Little Prickly Pear Creek, Dearborn River, and Sheep Creek into the Missouri River.
1741	Models are sorted by corrected Akaike information criterion (AIC _C) with log likelihood
1742	('LogLik'), difference in AIC _C from the best supported model (Δ AIC _C), and model weights
1743	(AIC _W). Models within < 4 AIC _C of the top model were included in the top model set and
1744	multimodel inference. Each model includes an intercept term and 'intercept only' denotes when
1745	no other predictors were included. Variance inflation factors are included for top models ('VIF')
1746	and for global models ('VIF _G '). R-squared values are also included for top models (' R^{2} ') and
1747	global models (' R^2_G '). Within VIF, 'ND' indicates that VIFs could not be calculated because < 2
1748	variables were included in that top model.

Site	Species	Num.	Model	df	LogLik	AIC _C	ΔAIC_{C}	AIC _W	VIF	VIF _G	\mathbb{R}^2	R^2_G
Little Prickly	Rainbow	1	Intercept + Discharge2 +	4	-118.49	245.13	0.00	0.36	0.140	< 1.66	0.141	< 1.68
Pear Creek	Trout		Photoperiod +									
		2	I emperature	2	120.27	246.92	1 70	0.15				
		Z	Photoperiod	3	-120.57	240.83	1.70	0.15				
		3	Intercept + Discharge? +	5	-118 31	246 85	1 72	0.15				
		5	Lunar phase +	5	110.51	210.05	1.72	0.15				
			Photoperiod +									
			Temperature									
		4	Intercept + Photoperiod	2	-121.55	247.13	2.00	0.13				
		5	Intercept + Photoperiod	3	-120.95	247.98	2.85	0.09				
			+ Temperature									
		6	Intercept + Discharge2 +	4	-120.29	248.74	3.60	0.06				
			Lunar phase +									
		_	Photoperiod	_								
		7	Intercept + Lunar phase + Photoperiod	3	-121.52	249.12	3.99	0.05				
	Brown	1	Intercept + Photoperiod	2	-62.48	129.01	0.00	0.21	0.007	NA	0.013	< 2.01
	Trout											
		2	Intercept only	1	-63.78	129.58	0.58	0.15				
		3	Intercept + Photoperiod + Temperature	3	-61.76	129.61	0.60	0.15				
		4	Intercept + Lunar phase + Photoperiod	3	-62.38	130.84	1.84	0.08				
		5	Intercept + Discharge ² + Photoperiod	3	-62.48	131.05	2.04	0.07				
		6	Intercept + Lunar phase	2	-63.67	131.38	2.37	0.06				

		7	Intercept + Discharge ² + Photoperiod + Temperature	4	-61.63	131.42	2.41	0.06				
		8	Intercept + Discharge ²	2	-63.70	131.44	2.44	0.06				
		9	Intercept + Lunar phase + Photoperiod + Temperature	4	-61.67	131.49	2.49	0.06				
		10	Intercept + Temperature	2	-63.78	131.60	2.60	0.06				
		11	Intercept + Discharge ² + Lunar phase + Photoperiod	4	-62.38	132.90	3.90	0.03				
Dearborn River	Rainbow Trout	1	Intercept + Discharge + Temperature	3	-80.79	167.67	0.00	0.20	0.031	< 1.09	0.030	< 2.45
		2	Intercept + Photoperiod	2	-82.05	168.13	0.47	0.16				
		3	Intercept + Photoperiod + Temperature	3	-81.37	168.82	1.16	0.11				
		4	Intercept + Discharge + Lunar phase + Temperature	4	-80.36	168.87	1.21	0.11				
		5	Intercept + Temperature	2	-82.71	169.47	1.80	0.08				
		6	Intercept + Discharge + Photoperiod + Temperature	4	-80.70	169.55	1.88	0.08				
		7	Intercept + Lunar phase + Photoperiod	3	-81.86	169.81	2.14	0.07				
		8	Intercept + Discharge + Photoperiod	3	-82.03	170.14	2.47	0.06				
		9	Intercept + Lunar phase + Photoperiod + Temperature	4	-81.17	170.49	2.82	0.05				
		10	Intercept + Discharge + Lunar phase + Photoperiod + Temperature	5	-80.32	170.86	3.20	0.04				
		11	Intercept + Lunar phase + Temperature	3	-82.51	171.10	3.44	0.04				
Sheep Creek	Rainbow Trout	1	Intercept + Temperature + Photoperiod	3	-51.19	108.47	0.00	0.30	0.053	< 1.62	0.059	< 2.78
		2	Intercept + Temperature + Lunar phase + Photoperiod	4	-50.56	109.26	0.79	0.20				
		3	Intercept + Discharge + Temperature + Photoperiod	4	-51.06	110.27	1.80	0.12				
		4	Intercept + Photoperiod	2	-53.21	110.47	2.00	0.11				
		5	Intercept + Lunar phase + Photoperiod	3	-52.49	111.06	2.59	0.08				
		6	Intercept + Discharge + Temperature + Lunar phase + Photoperiod	5	-50.50	111.22	2.75	0.08				
		7	Intercept + Discharge + Photoperiod	3	-52.93	111.96	3.49	0.05				

	8	Intercept + Discharge + Lunar phase + Photoperiod	4	-52.03	112.22	3.75	0.05
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1775 Figure 3.1. The upper Missouri, Sun, and Smith rivers and their major tributaries. Yellow dots

1776 represent USGS gaging stations used in the study. Black diagonals represent dams or diversions.

- 1777 Green diamonds represent fixed PIT antenna arrays. Shaded buffers represent areas where fish
- movement was monitored by fixed PIT antenna arrays, portable PIT antennas, and physical
- 1779 recapture events.
- 1780



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1782
1782 Figure 3.2. Dearborn River hydrograph and thermograph from 2014 to 2019 measured at the
1783 USGS gaging station (USGS site 06077200) near Craig, Montana.





Figure 3.3. Smith River hydrograph and thermograph from 2014 to 2019 measured at the USGSgaging station (USGS site 06077200) near Fort Logan, Montana.





Figure 3.4. Sun River hydrograph and thermograph from 2014 to 2019 measured at the USGSgaging station (USGS site 06077200) near Simms, Montana.





Figure 3.5. Little Prickly Pear Creek hydrograph 2014 to 2019 measured at the USGS gaging
station (USGS site 06077200) at the confluence with Wolf Creek.



1799 1800 Figure 3.6. Operation timelines of stationary PIT arrays in the Smith, Sun, and upper Missouri

1801 River subbasins from 2011 to 2020.





1803 Figure 3.7. Average read ranges of fixed PIT arrays by month from 2015 to 2019.



Figure 3.8. Little Prickly Pear Creek stream temperatures as a function of A) air temperatures
and B) stream discharges. Data collected from 2000 to 2006; only data from March through
November were included for analysis. Solid black lines are linear regression predictions. Gray

1809 bands represent 95% confidence intervals of the linear regression models. Black dots represent

1810 raw data.



1812 Figure 3.9. The relationship between Dearborn River discharge (USGS site 06073500; USGS

1813 2019) and Helena, Montana mean daily air temperature.



Figure 3.10. Length-frequency distributions of juvenile rainbow trout (TL < 201 mm) tagged in
(A) and outmigrated from (B) upper Missouri River tributaries in 2014. Except for 45 individuals

1817 tagged in the Dearborn River, all juvenile rainbow trout were tagged from March to May of

^{1818 2014.}





Figure 3.11. Length-frequency distributions of juvenile rainbow trout documented outmigrating

1821 from upper Missouri River tributaries in 2014 (A) and 2015 (B).



- 1822 1823 Figure 3.12. Outmigration pulses of tagged juvenile rainbow trout by month out of upper
- 1824 Missouri River tributaries in 2014. Red dots represent the proportion of fish that outmigrated that 1825
- month for each tributary. The darker the gradient, the higher the proportion.





1826 1827 Figure 3.13. Weekly outmigration of tagged juvenile rainbow trout out of the Dearborn River, 1828 Sheep Creek, and Little Prickly Pear Creek in 2014. Number of outmigrants out of Little Prickly 1829 Pear Creek include all fish tagged upstream in Lyons Creek, Wolf Creek, and Little Prickly Pear 1830 Creek. The solid blue line represents daily discharge collected at USGS gaging stations at Little 1831 Prickly Pear Creek (USGS site 06071300; 2019) and the Dearborn River (USGS site 06073500; 1832 2019). The red lines represent estimated Dearborn River and Little Prickly Pear Creek water 1833 temperatures. Discharge and temperature data for the Dearborn River were used as surrogates for

1834 Sheep Creek because data were not available.





Figure 3.14. Cumulative proportion of all juvenile rainbow trout that outmigrated into the

1837 Missouri River after being tagged in the Dearborn River, Sheep Creek, and Little Prickly Pear
 1838 Creek and its tributaries Lyons Creek and Wolf Creek in 2014. The solid blue line represents

1839 daily discharge collected at USGS gaging stations at Little Prickly Pear Creek (USGS site

1840 06071300; 2019) and the Dearborn River (USGS site 06073500; 2019).





Figure 3.15. Cumulative proportion of all juvenile rainbow trout that outmigrated from Wolf

1843 Creek and Lyons Creek into Little Prickly Pear Creek and then entered the Missouri River. Gray 1844 areas represent the cumulative proportion of fish outmigrating from either Wolf Creek or Lyons

1845 Creek and dark areas represent the cumulative proportion of those same fish outmigrating from

1845 Creek and dark areas represent the cumulative proportion of those same fish outingrating from 1846 Little Prickly Pear Creek into the Missouri River. The solid blue line represents daily discharge

1847 collected at the USGS gaging station on Little Prickly Pear Creek (USGS site 06071300; 2019).


Figure 3.16. Length-frequencies distributions of juvenile brown trout (TL < 201 mm) tagged in
(A) and outmigrated from (B) upper Missouri River tributaries in 2014. Except for 4 individuals
tagged in the Dearborn River, all juvenile brown trout were tagged from March to May of 2014.

1852 Too few brown trout were documented outmigrating from the Dearborn River, Sheep Creek,

- 1853 Lyons Creek, and Wolf Creek to display length-frequency distributions.
- 1854



1855 1856 Figure 3.17. Weekly outmigration of rainbow trout and brown trout tagged in Little Prickly Pear

1857 Creek and its tributaries Lyons Creek and Wolf Creek into the Missouri River in 2014. The solid

1858 blue line represents daily discharge collected at the USGS gaging station on Little Prickly Pear

1859 Creek (USGS site 06071300; 2019). The red line represents estimated Little Prickly Pear Creek

1860 water temperatures.



Figure 3.18. Cumulative proportion of juvenile rainbow trout and brown trout that outmigrated from Little Prickly Pear Creek and its tributaries into the Missouri River. The solid blue line represents daily discharge collected at the USGS gaging station on Little Prickly Pear Creek (USGS site 06071300; 2019).





1868 Figure 3.19. Length-frequency distributions of juvenile rainbow trout (TL < 201 mm) tagged in

1869 Smith River tributaries in 2014 (A) and outmigrated from Smith River tributaries in 2015 (B).

1870 Too few fish were detected outmigrating from Hound, Tenderfoot, and Moose creeks in 2015 to

1871 provide length-frequency distributions.



- 1872 1873 Figure 3.20. Length-frequency distributions of juvenile brown trout (TL < 201 mm) tagged in
- Smith River tributaries in 2014 (A) and outmigrated from Smith River tributaries in 2015 (B). 1874
- 1875 Too few fish were detected outmigrating from Tenderfoot, Sheep, and Moose creeks in 2015 to provide length-frequency distributions. 1876





Figure 3.21. Weekly outmigration in 2015 of juvenile rainbow trout tagged in Moose and Sheep creeks in 2014. The solid red line represents mean daily water temperature of the Smith River whereas the solid blue line represents daily discharge. Water temperature and discharge data was collected at the USGS gaging station just below Eagle Creek (USGS site 06077200; 2019).



Figure 3.22. Cumulative proportion of juvenile rainbow trout that outmigrated from Moose and
Sheep creeks into the Smith River in 2015. The solid red line represents mean daily water
temperature of the Smith River whereas the solid blue line represents daily discharge. Water
temperature and discharge data was collected at the USGS gaging station just below Eagle Creek
(USGS site 06077200; 2019).



Figure 3.23. Cumulative proportion of juvenile brown trout that outmigrated from Hound Creek
into the Smith River in 2015. The solid red line represents mean daily water temperature of the
Smith River whereas the solid blue line represents daily discharge. Water temperature and
discharge data was collected at the USGS gaging station on the Smith River near Eden, Montana
(USGS site 06077500; 2019).





Figure 3.24. Diel timing of outmigration of brown trout and rainbow trout from tributaries in the

1911 upper Missouri River subbasin (Dearborn River, Little Prickly Pear Creek, Lyons Creek, Wolf

1912 Creek, and Sheep Creek) in 2014 and Smith River subbasin (Sheep Creek, Moose Creek, and

1913 Hound Creek) in 2015.



1916 Figure 3.25. Diel timing of rainbow trout and brown trout in each Missouri River tributary in

1917 2014 and each Smith River tributary in 2015. Graphs depict outmigration of rainbow trout unless1918 otherwise specified.



1919
1920 Figure 3.26. Influence of photoperiod on the probability of outmigration of rainbow trout out of
1921 Little Prickly Pear Creek (A) and Sheep Creek (B).



6 Figure 3.27. Influence of mean water temperature on probability of rainbow trout outmigrating

1937 from Sheep Creek, Smith River (A) and influence of photoperiod on probability of rainbow trout

1938 outmigrating from Wolf Creek, Missouri River (B).

1941	CHAPTER FOUR
1942	
1943	GROWTH RATES AND AGE STRUCTURES OF SALMONIDS IN THE UPPER MISSOURI
1944	RIVER, SUN RIVER, AND SMITH RIVER
1945	
1946	Introduction
1947	
1948	Understanding age structure and growth patterns in salmonid populations is necessary for
1949	making sound management decisions but difficult when diverse life history patterns are present
1950	(Al-Chokachy and Budy 2008; Homel and Budy 2008). In the upper Missouri River, annual trout
1951	age studies were conducted for a 30-year period from 1981 to 2012 to evaluate and predict year-
1952	class strengths using scale patterns (Grisak et al. 2015). However, variability in life history
1953	aspects, particularly outmigration, may have produced variation in scale annulus formation and
1954	inconsistent results (Grisak et al. 2015).
1955	Known-age fish would provide a standard to evaluate historical studies and insights into
1956	current population structures. We used a combination of PIT telemetry and physical recaptures to
1957	determine growth rates and age structures of rainbow trout, brown trout, and mountain whitefish
1958	in the upper Missouri, Sun, and Smith rivers. Our objective was to compare growth rates and age
1959	structures among upper Missouri River, Sun River, and Smith River salmonid populations, and
1960	evaluate accuracy of previous age and growth methodologies.
1961	
1962	Methods
1963	
1964	<u>PIT-tagging</u>

1965A total of 11,936 fish was tagged in the upper Missouri River basin from 2010 to 2019;19663,572 in the upper Missouri River subbasin (Table 4.1), 739 in the Sun River subbasin (Table19674.2), and 7,625 in the Smith River subbasin (Table 4.3). From 2010 to 2012, 777 fish were1968tagged as part of a Montana State University graduate study investigating Tenderfoot Creek, a1969major tributary of the Smith River (Ritter 2015). Most of these fish were likely not present from19702014 to 2019; however, some fish tagged in 2012 were active until at least 2018 (Mullen and1971Vivian 2019).

1972 Fish were collected with boat, barge, and backpack electrofishers, and fyke nets, 1973 anesthesized with Aqui-S 20E (Aqui-S New Zealand Ltd.; 10 to 20 mg/L) or MS-222 (tricaine 1974 methanesulfonate; 50 mg/L), and implanted with HDX PIT tags. Location, species, and total 1975 length (TL) were recorded for each fish at the time of tagging; 20% (2,389 of 11,936) were also 1976 weighed. The date when a fish was collected and tagged was recorded as the first observation for 1977 each individual. PIT tags were surgically implanted into the abdominal cavity through small 1978 incisions made by a small scalpel coated with antiseptic. Most fish were tagged with 23 or 32-1979 mm HDX PIT tags; a small number of fish (217 of 11,936) were tagged with 12-mm HDX PIT 1980 tags. Lengths and weights of recaptured fish were also recorded to investigate age and growth. 1981

1982 <u>Monitoring fish movement</u>

A network of 23 stationary PIT arrays monitored the movements of PIT-tagged fish throughout the upper Missouri River basin (Table 4.4 and Figure 4.1). Five arrays were installed in the upper Missouri River subbasins in the spring of 2014, three arrays were installed in the Sun River subbasin in the spring of 2015, and 15 arrays were installed in the Smith River subbasin from 2014 to 2016 (Table 4.4 and Figure 4.1). These monitoring stations ran in some combination from 2010 to 2019 (Figure 4.2). The Dearborn River, Little Prickly Pear Creek,
Truly Bridge, and Hound Creek arrays were damaged by flows in the spring and early summer of
2018. All but Truly Bridge were repaired and reinstalled. Five stations were operated in
Tenderfoot Creek from 2010 to 2014, but only one array installed at the mouth of Tenderfoot
Creek was maintained after 2013 (Table 4.4 and Figure 4.1; Ritter 2015). Age and growth
analyses used data collected prior to 2014 and afterward, but all other analyses were restricted to
data collected after 2013.

1995 Antenna stations consisted of a PIT-tag reader (Oregon RFID, multi-antenna HDX reader 1996 and long-range HDX reader, Portland, Oregon), one to two stream-width antennas, and a tuning 1997 board for each antenna (Oregon RFID, standard remote tuner board and long-range tuner board, 1998 Portland, Oregon). Antenna arrays were powered by 12-V DC supplied by either solar panels or 1999 120-V AC converters. Antennas were placed in areas where fish would unlikely stay for long 2000 periods of time (e.g., riffles and shallow water habitat) to prevent many consecutive detections 2001 and to monitor interchange between mainstem river and tributaries (rather than localized use near 2002 the antennas). All antennas were oriented flat on the bottom (swim over or flat-bed design; 2003 Armstrong et al. 1996) and tuned to best possible vertical read ranges for tags oriented 2004 perpendicularly to the antennas.

Mobile PIT arrays were used to actively monitor fish movements and complement the network of fixed monitoring stations. Mobile tracking was conducted using raft, kayak, and polemounted antennas (Hill et al. 2006; McKinstry and Mackinnon 2011); methods are explained in detail by Lance 2019. In the upper Missouri Sun rivers, mobile tracking by raft and kayak was conducted in 2015 and 2016 but discontinued thereafter because of low detection range. A polemounted antenna was used in 2016 to scan tributaries and islands of the upper Missouri River and American white pelican *Pelecanus erythrorhynchus* nesting islands in Canyon Ferry and
Arod Lake (Vivian and Mullen 2018). In the Smith River, all forms of mobile tracking were used
to track fish from 2015 to 2017 (Lance 2019). No mobile tracking was conducted from 2018
onward.

- 2015
- 2016

Data analysis

2017

2018 In addition to physical recapture events, we used detection intervals to investigate 2019 longevity of rainbow trout, brown trout, and mountain whitefish in all subbasins. Detection 2020 intervals were calculated using the initial date of detection and final date of detection collected 2021 by fixed PIT array, mobile tracking, or physical recapture events. We also plotted distributions of 2022 length at tagging and detection interval associations to estimate observed longevities. For 2023 example, an individual detected after 4 years with an initial tagging length of 300 mm was likely 2024 older than an individual with the same detection interval but initial tagging length of 100 mm. 2025 Growth rates of salmonids vary seasonally and by age, so comparisons should be 2026 interpreted with caution. Intervals between capture events varied and often exceeded one year, 2027 frequently encompassing differing numbers of growing seasons. Moreover, in the upper Missouri 2028 River subbasin, our yearly means were calculated over an average of 3.5 years and probably not 2029 representative of age-specific yearly growth. For example, rainbow trout captured in the Dog 2030 Creek subwatershed (Montana Fish, Wildlife & Parks Cascade sampling section) by Grisak et al. 2031 (2015) exhibited mean yearly growth from age-1 to age-2 of 99 mm (3.9"), whereas mean yearly 2032 growth from age-3 to age-4 was 48 mm (1.9"). Even so, some comparisons were made by

2033 calculating yearly growth rates over similar intervals using those determined by Grisak et al.2034 (2015).

2035	We used box and whisker plots and growth curves as graphical representations of growth
2036	rate comparisons. We used t-tests to compare annual growth rates within species between
2037	subbasins and Kruskal-Wallis one-way ANOVAs to compare growth rates of brown trout among
2038	subbasins and growth rates of all species combined among subbasins. Unfortunately, too few
2039	individuals were collected for reliable comparisons of growth rates between fish tagged in the
2040	mainstem and tributaries so lengths at tagging were compared by location instead. Outliers
2041	(negative values and values exceeding 200 mm annually), presumably a result of discrepancies in
2042	field measurements or data entry, were excluded from both analyses and graphical
2043	representations. The statistical software programs R (v4.0.2; R Core Team 2019) and SigmaPlot
2044	14 (SigmaPlot 2017) were used for analyzing and plotting trends and comparisons in
2045	outmigration timing and magnitude.
2046	
2047	Results
2048	
2049	Upper Missouri River subbasin
2050	All species of fish tagged in the mainstem were larger than those tagged in tributaries (p
2051	= 0.001).
2052	
2053	Rainbow trout
2054	Most rainbow trout tagged in the upper Missouri River and its tributaries were smaller
2055	than 240 mm (9.5"); mean length was 177 mm (7.0"; Figure 4.3). Tagging lengths ranged from

2056 76 mm (3.0") to 511 mm (20.1"; Figure 4.3). Mean relative weight of the five fish captured and 2057 weighed was 95.7 (Table 4.5).

The mean time interval between the date tagged and date of last detection of the 713 2059 redetected rainbow trout was 1.4 years and reached 5.2 years (Figure 4.4). All rainbow trout 2060 redetected for at least 3 years had a tagging length less than 300 mm (11.8"; Figure 4.5). 2061 However, there were five rainbow trout redetected after 2.5 years that had tagging lengths greater 2062 than 400 mm (15.7"; Figure 4.5).

2063 Seven rainbow trout tagged in the upper Missouri River subbasin were recaptured, 2064 measured, and weighed (Table 4.6). Intervals between initial tagging date and date of recapture 2065 ranged from 3.4 to 4.5 years. Rainbow trout collected by Grisak et al. (2015) in the Dog Creek 2066 subwatershed had an average yearly growth of 87 mm (3.4") from age-0 to age-3 over the 30-2067 year study period, whereas we observed an average yearly growth rate of 71 mm (2.8") over an 2068 average interval of 3.5 years and ranged from 43 mm/year (1.7 inches/year) to 102 mm/year (4.0 2069 inches/year; Table 4.6 and Figure 4.6). Mean yearly growth rate of brown trout from age-1 to 2070 age-4 determined by Grisak et al. (2015) was higher than what we observed (99 mm/year 2071 compared to 88 mm/year, respectively). Yearly and overall growth rates appeared higher in the 2072 Missouri River than those observed in the Smith River (Figures 4.6 and 4.7), but differences in 2073 yearly growth rates were not statistically significant (P = 0.15).

2074

2058

2075 Brown trout

2076 Most brown trout tagged in the upper Missouri River and its tributaries were smaller than 2077 240 mm (9.5"); mean length was 205 mm (8.1"; Figure 4.3). Tagging lengths ranged from 76

2078 mm (3.0") to 508 mm (20."; Figure 4.3). Mean relative weight of the 11 fish captured and 2079 weighed was 96.3 (Table 4.5).

The mean time interval between the date tagged and date of last detection of the 124 redetected brown trout was 1.7 years and reached 6.0 years (Figure 4.4). Two brown trout redetected after at least 5 years had tagging lengths greater than 240 mm (9.4"; Figure 4.5). A brown trout measuring 107 mm (4.2") at tagging had the longest interval between tagging and last detection (6.0 years) of any fish of any species tagged in the upper Missouri River (Figure 4.5). The last detection of this fish was a recapture during annual population sampling (rather than a detection on a fixed PIT antenna).

2087 Six brown trout tagged in the upper Missouri River subbasin were recaptured, measured, 2088 and weighed (Table 4.6). Three individuals were recaptured twice and one individual was 2089 recaptured three times (Table 4.6). Intervals between initial tagging date and date of recapture 2090 ranged from 0.8 to 4.0 years (Table 4.6). Yearly growth had a mean of 54 mm/year (2.1 2091 inches/year) and ranged from 7 mm/year (0.3 inches/year) to 104 mm/year (4.1 inches/year; 2092 Table 4.6 and Figure 4.6). Mean yearly growth of initial recaptures was 88 mm/year (3.5"/year) 2093 and ranged from 69 mm/year (2.7"/year) to 104 mm/year (4.1"/year). Yearly and overall growth 2094 rates appeared higher in the Missouri River than those observed in the Sun and Smith rivers 2095 (Figures 4.6 and 4.7), but differences in yearly growth rates were not statistically significant (P =2096 0.111).

2097

2098 Mountain whitefish

2099 Most mountain whitefish tagged in the upper Missouri River and its tributaries were 2100 larger than 300 mm (11.8"); mean length was 377 mm (14.8"; Figure 4.3). Tagging lengths

2101	ranged from 127 mm (5.0") to 506 mm (19.9"; Figure 4.3). No mountain whitefish were
2102	captured and weighed in the upper Missouri River.
2103	The time interval between the date tagged and date of last detection of the 81 redetected
2104	mountain whitefish had a mean of 1.4 years and maximum of 4.1 years (Figure 4.4). Only one
2105	mountain whitefish was redetected after four years, but this individual had a tagging length of
2106	363 mm (14.3"; Figure 4.5). Half of the eight mountain whitefish were redetected after at least
2107	three years and had tagging lengths greater than 400 mm (15.7"; Figure 4.5). All but four
2108	mountain whitefish redetected in the upper Missouri River had tagging lengths greater than 300
2109	mm (11.8"; Figure 4.5).
2110	
2111	Sun River
2112	Combined yearly growth rates of all species were lower than those of the upper Missouri
2113	and Smith River subbasins ($p = 0.005$).
2114	
2115	Rainbow trout
2116	The size distribution of rainbow trout tagged in the Sun River was mostly normal; mean
2117	length was 315 mm (12.4"; Figure 4.8). Tagging lengths ranged from 135 mm (5.3") to 541 mm
2118	(21.3"; Figure 4.8). No rainbow trout were captured and weighed in the Sun River.
2119	The mean time interval between the date tagged and date of last detection of the 31
2120	redetected rainbow trout was 0.6 years and reached 3.0 years (Figure 4.4). Only one individual

was redetected after 3 years and had a tagging length of 333 mm (13.1"; Figure 4.5). Only three

rainbow trout were redetected after at least two years, but all had tagging lengths greater than

2121

2122

2123

300 mm (11.8"; Figure 4.5).

2125 Brown trout

2126	Most brown trout tagged in the Sun River were larger than 300 mm (11.8"); mean length
2127	was 340 mm (13.4"; Figure 4.8). Tagging lengths ranged from 125 mm (4.9") to 528 mm (20.8";
2128	Figure 4.8). Mean relative weight of the five fish captured and weighed was 88.0 (Table 4.5).
2129	The time interval between the date tagged and date of last detection of the 72 redetected
2130	brown trout had a mean of 1.3 years and maximum of 5.1 years (Figure 4.4). Most brown trout
2131	were redetected after 3.2 years or less; the five brown trout redetected after at least four years
2132	were recaptured during annual population sampling (rather than detected on PIT antennas).
2133	These individuals had tagging lengths ranging from 259 mm (10.2") to 447 mm (17.3") and were
2134	the only fish measured and weighed (Table 4.6). Yearly growth rates had a mean of 23.4
2135	mm/year (0.9 inches/year) and ranged from 11 mm/year (0.4 inches/year) to 46 mm/year (1.8
2136	inches/year; Table 4.6 and Figure 4.6). Yearly growth rates appeared lower than those observed
2137	in the upper Missouri River and Smith River (Figure 4.6). Overall growth rates of brown trout
2138	with similar tagging lengths also appeared lower than those observed in the other subbasins
2139	(Figure 4.7).
0 1 40	

2140

2141 Mountain whitefish

The size distribution of mountain whitefish tagged in the Sun River was mostly normal; mean length was 318 mm (12.5"; Figure 4.8). Tagging lengths ranged from 165 mm (6.5") to 472 mm (18.6"; Figure 4.8). Mean relative weight of the three fish captured and weighed was 99.5 (Table 4.5).

2146	The time interval between the date tagged and date of last detection of the 49 redetected
2147	mountain whitefish had a mean of 1.2 years and maximum of 4.1 years (Figure 4.4). Five
2148	mountain whitefish were redetected after at least 3 years and all had tagging lengths greater than
2149	280 mm (11"). Two mountain whitefish were redetected after at least four years and had tagging
2150	lengths of 345 mm (13.6") and 368 mm (14.5"; Table 4.6). Both individuals were recaptured
2151	during annual population sampling.
2152	Three mountain whitefish tagged in the Sun River were recaptured, measured, and
2153	weighed (Table 4.6). Intervals between initial tagging date and date of recapture were 3.1, 4.0,
2154	and 4.1 years (Table 4.6). Yearly growths were 9 mm/year (0.4 inches/year), 11 mm/year (0.4
2155	inches/year), and 16 mm/year (0.6 inches/year; Table 4.6 and Figure 4.6). Yearly and overall
2156	growth rates appeared similar to those observed in the Smith River (Figures 4.6 and 4.7; $P =$
2157	0.457).

2159 Smith River

2160 Rainbow trout

2161 Most rainbow trout tagged in Smith River tributaries were smaller than 240 mm (9.5"), 2162 whereas the opposite was true for fish tagged in the mainstem river (Figure 4.9). Mean length of 2163 all tagged rainbow trout was 210 mm (8.3"; Figure 4.9). Tagging lengths ranged from 46 mm 2164 (1.8") to 511 mm (20.1"; Figure 4.9). Mean relative weight of the 606 fish captured and weighed 2165 was 91.6 (Table 4.5). Relative weight was highest in the South Fork Smith River watershed and 2166 was generally higher in upper (southernmost) watersheds (Figure 4.10). 2167 The time interval between the date tagged and date of last detection of the 1,584 2168 redetected rainbow trout had a mean of 1.6 years and maximum of 6.7 years (Figure 4.4). Three

rainbow trout were redetected after at least 6 years (Figure 4.5). Of the ten rainbow trout
redetected after at least five years, all but three had tagging lengths greater than 200 mm (Figure
4.5), and all were tagged in either 2010 or 2011 during the Tenderfoot Creek graduate study
(Table 4.6).

One hundred and five rainbow trout tagged in the Smith River were recaptured,
measured, and weighed (Table 4.6). Ten individuals were recaptured twice (Table 4.6). Intervals
between initial tagging date and date of recapture had a mean of 1.2 years and ranged from 0.8 to

2176 4.0 years (Table 4.6). Mean yearly growth was 55 mm/year (2.1 inches/year) and ranged from 0

2177 mm/year (0.3 inches/year) to 217 mm/year (8.5 inches/year; Table 4.6 and Figure 4.6). Yearly

2178 growth rates appeared lower than those observed in the Missouri River (Figure 4.6).

2179

2180 Brown trout

Size distributions of brown trout tagged in tributaries and mainstem of the Smith River were mostly normal, although there were more brown trout less than 200 mm (7.9") tagged in tributaries (Figure 4.9). Mean length of all tagged brown trout was 318 mm (12.5"; Figure 4.9). Tagging lengths ranged from 61 mm (2.4") to 660 mm (26.0"; Figure 4.9). Mean relative weight of the 437 fish captured and weighed was 95.0 (Table 4.5). Relative weight was highest in the South Fork Smith River watershed and tended to be higher in upper (southernmost) watersheds (Figure 4.11).

The time interval between the date tagged and date of last detection of the 552 redetected brown trout had a mean of 1.3 years and maximum of 6.6 years (Figure 4.4). Four brown trout were redetected after at least five years; three of these individuals had tagging lengths greater than 400 mm (15.7"; Figure 4.5). One of these individuals was tagged in 2014, the other three
were tagged in either 2010 or 2011 (Table 4.6).

Twenty-eight brown trout tagged in the Smith River were recaptured, measured, and weighed (Table 4.6). Four individuals were recaptured twice (Table 4.6). Intervals between initial tagging date and date of recapture had a mean of 1.2 years and ranged from 0.1 to 3.0 years (Table 4.6). Mean yearly growth was 82 mm/year (3.2 inches/year) and ranged from 0 mm/year to 191 mm/year (7.5 inches/year; Table 4.6 and Figure 4.6). Yearly growth rates appeared lower than those observed in the Missouri River (Figure 4.6).

2200 Mountain whitefish

2201 Size distributions of mountain whitefish tagged in tributaries and the mainstem of the 2202 Smith River were mostly normal, although there were more individuals less than 300 mm (11.8") 2203 tagged in tributaries (Figure 4.9). Mean length of all tagged mountain whitefish was 300 mm 2204 (11.8"; Figure 4.9). Tagging lengths ranged from 76 mm (3.0") to 597 mm (23.5"; Figure 4.9). 2205 Mean relative weight of the 1,132 fish captured and weighed was 99.1 (Table 4.5). Relative 2206 weight was highest in the Newlan Creek watershed and tended to be higher in upper 2207 (southernmost) watersheds (Figure 4.12). 2208 The time interval between the date tagged and date of last detection of the 1,447

redetected mountain whitefish had a mean of 1.7 years and maximum of 7.3 years (Figure 4.9). Eight mountain whitefish were redetected after at least six years; all of these individuals had tagging lengths greater than 200 mm (7.9") and were tagged in 2011 or 2012 (Figure 4.5). Two individuals were redetected after more than seven years; these fish had tagging lengths of 236 mm (9.3") and 308 mm (12.1") and were tagged in Tenderfoot Creek in 2012 (Table 4.6).

2214	Twenty-one mountain whitefish tagged in the Smith River were recaptured, measured,
2215	and weighed (Table 4.6). One individual was recaptured twice (Table 4.6). Intervals between
2216	initial tagging date and date of recapture had a mean of 1.1 years and ranged from 0.1 to 2.5
2217	years (Table 4.6). Mean yearly growth was 20 mm/year (0.8 inches/year) and ranged from 0
2218	mm/year to 78 mm/year (3.1 inches/year; Table 4.6 and Figure 4.6). Yearly growth rates
2219	appeared lower than those observed in the Sun River (Figure 4.6).
2220	
2221	Discussion and comparisons to previous studies
2222	
2223	Calculation of growth rates and assessment of age structures were difficult because of
2224	variability in location data and intervals between physical recaptures and detections. Reported
2225	growth rates and ages are rough estimates without full knowledge of the life history of each
2226	recaptured and detected individual. We make comparisons to previous studies, but proper
2227	evaluation of the methodologies used therein was not possible.
2228	Growth rates observed by Grisak et al. (2015) were generally higher than what we
2229	observed, potentially because fish were collected in the productive mainstem Missouri River
2230	whereas we initially captured some individuals in tributaries. Even though eventual recaptures
2231	occurred in the mainstem Missouri River, the duration of time individuals spent in tributaries
2232	may have slowed growth rates. Evidence of the continued annual increases in age at length of
2233	rainbow trout observed by Grisak et al. (2015) was difficult to distinguish because of low sample
2234	size and inconsistent intervals between captures.
2235	Growth rates among all species in the upper Missouri River were higher than those
2236	observed in the Sun and Smith rivers even though sample sizes of physical recaptures in the

2237 Missouri and Sun rivers generally precluded statistically significant results. Indeed, the tailwater 2238 fishery below Holter Dam in the Missouri River is generally accepted as one of the most 2239 productive in Montana (Grisak et al. 2012b). High summer water temperatures and low 2240 discharges resulting from irrigation withdrawals may be limiting factors of growth rate in the 2241 Sun and Smith rivers (Ritter 2015; Vivian and Mullen 2017; Ritter et al. 2020). 2242 Rainbow trout ages based on detection intervals and lengths at tagging were consistent 2243 with that observed by Grisak et al. (2015) in the Cascade sampling section (Dog Creek 2244 subwatershed). Estimated ages of physical recaptures also supported Grisak et al. (2015); age-4 2245 fish ranged from 432 mm (17.0") to 465 mm (18.3"). Detection intervals suggested brown trout 2246 reached at least seven to eight years of age; one seven-year old fish that was recaptured measured 2247 521 mm (20.5"), which was slightly less than the mean (but still within ranges) reported by 2248 Grisak et al. (2015) for brown trout captured in the Cascade sampling section. 2249 Fish in the Smith River were the longest-lived compared to the Sun and upper Missouri 2250 rivers. Although PIT arrays monitored detected fish in the Smith River for the longest duration 2251 (2011 to 2020), redetected fish also tended to have the highest combination of detection interval 2252 and length at tagging. Two rainbow trout tagged around 140 mm (5.5") in length were redetected 2253 after 6.7 years, suggesting these fish were approaching seven to eight years of age. Several 2254 brown trout with tagging lengths greater than 400 mm (15.7") were redetected after five to 6.5 2255 year intervals, suggesting these fish could have been approaching eight to ten years of age. 2256 Furthermore, physical recaptures showed a much slower growth rate than that observed in the 2257 Missouri River, which is not surprising based on direct growth rate comparisons. 2258 Longevity in the Sun River was more difficult to determine because duration of PIT array 2259 operation was limited. Rainbow trout probably reached five to seven years of age; one individual

with a tagging length of 333 mm (13") was detected after an interval of three years. Observed
lifespans of brown trout may have been seven to nine years old; one individual with a tagging
length of 389 mm (15.3") was detected after an interval of 5 years.

2263 Mountain whitefish exhibited the highest propensity to reach old ages in all subbasins, 2264 especially the Smith River. The longest detection intervals in the study were two mountain 2265 whitefish at 7.3 years. Furthermore, these fish were several years old at the time of initial capture; tagging lengths were 304 mm (12") and 236 mm (9.3"), suggesting these fish were at 2266 2267 least nine to ten years old. This longevity is well-documented in other systems; 90% of 2268 populations surveyed in Idaho showed individuals reaching at least ten years old (Meyer et al. 2011). Unsurprisingly, mountain whitefish exhibited the highest survival probability among 2269 2270 species in the Smith River subbasin (Lance 2019).

2271 Relative weights in the Smith River appeared highest in upstream watersheds for all 2272 species but may have been affected by low sample sizes for rainbow and brown trout. Lance 2273 (2019) identified these watersheds (Camas Creek, Newlan Creek, North Fork Smith River, and 2274 South Fork Smith River watersheds) as the headwaters geomorphic region. Characterized by an 2275 unconstrained agricultural valley (Lance 2019), the nutrient input from land management 2276 practices and agricultural operations may have increased productivity and subsequent body 2277 condition of individual fish, even though survival probabilities were highest in the canyon 2278 geomorphic region (Deep Creek, Tenderfoot Creek, Rock Creek, Eagle Creek, and Sheep Creek 2279 watersheds; Lance 2019).

TABLES

Table 4.1. Number of fish tagged by species and subwatershed in the Missouri River subbasin

from 2014 to 2016. Superscripts represent subwatersheds that include locations of annual

population sampling. Miscellaneous species include Mountain Sucker, Yellow Perch, and

Walleye.

					Species				
Subwatershed	rainbow trout	Brown Trout	Mountain Whitefish	Brook Trout	Burbot	White Sucker	Longnose Sucker	Misc	Total
Tributary									
Dearborn River	390	131	46	-	-	40	46	2	655
Sheep Creek Little Prickly Pear Creek watershed Little Prickly	424	72	-	-	-	2	-	-	498
Pear Creek	521	86	1	-	-	9	2	-	619
Wolf Creek	760	94	-	-	-	-	-	-	853
Lyons Creek	263	114	-	-	-	1	-	-	377
Subtotal	2,358	495	47	-	-	52	48	2	3,002
Mainstem									
City of Great Falls	3	6	7	-	1	2	1	1	21
Dog Creek ¹	66	68	4	-	-	23	1	-	162
Finigan Creek ²	8	4	-	-	-	-	-	-	12
Log Gulch	37	59	114	-	1	-	-	-	211
Prewett Creek	10	-	105	-	-	26	1	1	143
Wilson Butte	4	1	-	-	15	-	1	-	22
Subtotal	128	138	230	-	17	51	4	2	570
Total	2,487	633	277	-	17	103	52	4	3,572

2288 2289 ¹ Craig annual population sampling section.

² Cascade annual population sampling section.

Table 4.2. Number of fish tagged by species and subwatershed in the Sun River subbasin from

2297 2015 to 2016. Superscripts represent subwatersheds that include locations of annual population

sampling. Miscellaneous species include Mountain Sucker, Yellow Perch, and Walleye.

					Spec	cies			
	Subwatershed	Rainbow Trout	Brown Trout	Mountain Whitefish	Brook Trout	Burbot	White Sucker	Longnose Sucker	Total
	Tributary								
	Elk Creek	9	125	46	3	-	2	-	142
	Mainstem								
	City of Simms ¹	96	128	145	-	-	5	-	374
	Cutting Shed Coulee	48	100	76	-	-	-	-	223
	Subtotal	144	228	221	-	-	5	-	597
2200	Total	153	353	223	3	-	8	-	739
2299 2300	¹ Simms annual popul	lation sampling s	ection.						
2301									
2302									
2303									
2304									
2305									
2306									
2307									
2308									
2309									
2310									
2311									
2312									

Table 4.3. Number of fish tagged by species and subwatershed in the Smith River subbasin from

2010 to 2017. Superscripts represent subwatersheds that include locations of annual population

sampling.

-					Species				
Subwatershed	Rainbow Trout	Brown Trout	Mountain Whitefish	Brook Trout	Burbot	White Sucker	Longnose Sucker	Mountain Sucker	Total
Tributary									
Big Birch Creek	8	56	10	11	-	3	-	-	88
Hound Creek	24	367	11	-	-	48	19	-	469
Newlan Creek	1	21	5	33	8	46	-	-	114
Sheep Creek watershed									
Lower Sheep	51	26	120	1	-	9	1	-	208
Middle Sheep	689	77	52	13	-	2	-	-	833
Upper Sheep	284	40	40	4	-	2	-	-	370
Moose Creek	908	6	271	21	-	-	-	-	1,204
Rock Creek	13	68	17	-	-	-	-	-	98
Tenderfoot Creek	483	85	460	94	-	-	-	-	1,122
Subtotal	2,455	706	986	166	8	110	20	-	4,451
Mainstem									
Bear Gulch	42*	48	59	-	-	-	2	-	151
Blacktail Creek1	376	172	258	-	6	5	7	-	824
Boston Coulee	18*	38	129	-	-	8	7	-	200
Cottonwood Creek ²	56*	93	211	7	3	6	6	-	381
Rock Springs Creek	38*	178	235	8	2	23	-	-	484
Rocky Coulee	56	47	113	-	-	3	2	-	221
Two Creek	277*	187	356	-	13	12	12	1	858
Subtotal	864	763	1,360	15	24	57	36	-	3,119
Total	3,323	1,510	2,346	192	32	167	56	1	7,625

2317

¹ Eagle Creek annual population sampling section.
 * Includes one Westslope Cutthroat Trout. A total of five was tagged in the Smith River subbasin.

Table 4.4. Locations, average detection ranges, and detection efficiencies of stationary PIT

Stationary PIT array	GPS coordinates (UTM)	Tag detection distance (inches)	Detection efficiency	Physical location
		Missouri Riv	ver	
Lyons Creek	46.93827, -112.12581	28.5 (6 - 54)	-	Just upstream of confluence with Little Prickly Pear Creek
Wolf Creek Little Prickly Pear	47.00597, -112.08026	29 (6 - 60)	-	Little Prickly Pear Creek
Creek	47.02251, -112.02018	17 (2 – 42)		Missouri River Just upstream of confluence with
Dearborn River	47.13017, -111.91295	6.3 (2.5 – 9)	-	Missouri River Just upstream of confluence with
Sheep Creek	47.17681, -111.81165	17.7 (4 – 36) Sun River	-	Missouri River
				Just upstream of Hwy 287 near
HWY 287 Elk Creek	47.54768, -112.36674 47.51229, -112.33641	8.6 (4.5 – 18) 30 (4 – 48)	-	Augusta, Montana at rkm 109 rkm 4.5
Durocher	47.54413, -111.57848	7.2 (3 – 18)	-	Upstream of Vaughn, Montana at rkm 32
		Smith Rive	r	
Big Birch Creek	46.58884, -111.05305	-	0.79	Just upstream of confluence with Smith River
				Just upstream of confluence with
Newlan Creek	46.59094, -111.05070	-	0.79	Smith River
Canyon Ranch	46.60810, -111.06760	-	0.96	rkm 172 Just upstream of confluence with
Benton Creek	46.70542, -111.19305	-	0.79	Smith River Just upstream of confluence with
Camas Creek Smith River at	46.70542, -111.19305	-	0.96	Smith River
Beaver Creek	46.75143, -111.16839	-	1.00	rkm 141 Just upstream of confluence with
Moose Creek	46.80292, -110.91484	-	0.96	Sheep Creek
Upper Sheep Creek Lower Sheep	46.81047, -110.92272	-	0.71	1 rkm downstream of Moose Creek 0.9 rkm upstream of confluence with
Creek	46.80443, -111.17403	-	0.78	Smith River Just upstream of confluence with
Rock Creek	46.86935, -111.27185	-	0.79	Smith River Just upstream of confluence with
Tenderfoot Creek	46.94185, -111.29404	-	0.98	Smith River
Castle Bar	46.97789, -111.28427	-	0.75	rkm 97 Just downstream of Merganser Bend
Merganser Bend	47.14734, -111.294	-	0.66	boat camp
Hound Creek	47.21261, -111.40371	18.5 (4 - 36)	0.96	rkm 2.4
Truly Bridge	47.35658, -111.44140	7.4 (1 – 18)	0.70	rkm 14.6

arrays in the upper Missouri River, Sun River, and Smith River subbasins.

2328

2330 Table 4.5. Means and ranges of relative weights of rainbow trout, brown trout, and mountain

2331 whitefish measured, weighed, and tagged in the upper Missouri River, Sun River, and Smith

2332 River subbasins.

	Taxon	Ν	Mean	Minimum	Maximum
		Mi	ssouri River		
	Rainbow Trout	5	95.7	87.3	104.5
	Brown Trout	11	96.3	80.3	132.0
	Mountain Whitefish	-	-	-	-
	Dainhaw Trout		Sun River		
	Raindow I rout	- 5	-	- 02 /	-
	Mountain Whitefish	3	00.0 00.5	03.4	95.0
	Wouldarn wintensii	S SI	nith River	95.5	108.2
	Rainbow Trout	606	91.6	53.2	187.1
	Brown Trout	437	95.0	47.1	131.1
	Mountain Whitefish	1.132	99.1	50.0	179.2
2333		-,			
2000					
2224					
2334					
0005					
2335					
2336					
2337					
2338					
2330					
2220					
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2340					

Table 4.6. Summary of tagged fish recaptured in the upper Missouri River, Sun River, and Smith

2348 River subbasins from 2014 to 2020.

PIT	Date tagged	Subwatershed tagged	Tagging length, weight (mm_kg)	Date recaptured	Subwatershed recaptured	Recapture length, weight (mm_kg)	Time to recapture (years)	Growth (mm)	Growth rate (mm/year)
Missouri River			(11111, 115)			(11111, 115)			
				Rainbow Tr	out				
384.3515DD8A5A	3/12/2014	Wolf Creek	102	9/28/2017	Log Gulch	465, 1.0	3.55	363	102
384.3515DD8CC0	4/2/2014	Sheep Creek	119	10/10/2017	Log Gulch	460, 1.1	3.53	340	96
204 2515DD0DEE	2/28/2014	Little Prickly	140	0/27/2017	L Culab	422 0.8	2.51	202	02
384.3515DD8DEF	3/28/2014	Little Prickly	140	9/27/2017	Log Gulch	432, 0.8	3.51	292	83
384.3515DD8FAE	3/20/2014	Pear Creek	196	10/1/2018	Log Gulch	445	4.54	249	55
384.3515DDF963	4/28/2014	Dog Creek	254	9/27/2017	Log Gulch	406, 0.7	3.42	152	45
384.3515DDF9A2	4/29/2014	Dog Creek	282	10/11/2017	Log Gulch	432, 0.9	3.46	150	43
384.3515DDF9F1	5/6/2014	Dog Creek	211	10/10/2017	Log Gulch	483	3.43	272	79
				Brown Tro	ut				
384.3515DD91A8	3/11/2014	Wolf Creek	170	5/3/2017	Log Gulch	432, 0.8	3.15	262	83
				4/24/2018	Log Gulch	442, 0.7	0.97	10	10
384.3515DDF960	4/28/2014	Dog Creek	244	5/3/2017	Log Gulch	452, 1.3	3.02	208	69
				4/24/2018	Log Gulch	470, 1.3	0.97	18	18
				4/29/2020	Dog Creek	488, 1.2	2.02	18	9
384.3515DDF96E	4/28/2014	Dog Creek	107	4/23/2018	Log Gulch	505, 1.2	3.99	399	100
				5/13/2020	Dog Creek	521, 1.2	2.06	15	7
384.3515DDF9BF	5/5/2014	Dog Creek	180	5/3/2017	Log Gulch	450, 0.9	3.00	269	90
				4/23/2018	Log Gulch	467, 0.9	0.97	18	18
384.3515DDFBCE	5/5/2014	Log Gulch	168	4/23/2018	Log Gulch	493, 1.2	3.97	325	82
384.3515DDFC27	5/7/2014	Log Gulch	234	5/3/2017	Log Gulch	546, 1.7	2.99	312	104
Sun River									
				Brown Tro	ut .				
		City of			Cutting Shed				
384.3515DE9C23	3/19/2015	Simms Cutting Shad	259	4/15/2019	Coulee	447, 0.9	4.08	188	46
20/ 2500111660	2/22/2015	Cutting Sheu	280	2/20/2020	Cutting Sheu	460.0.0	5.02	71	14
504.550D11A0A0	5/25/2015	Cutting Shed	309	3/30/2020	Cutting Shed	400, 0.9	5.02	/1	14
384 358011 4608	3/23/2015	Coulee	131	4/4/2010	Coulee	478 1 0	4.03	13	11
504.550D11A0D0	5/25/2015	Cutting Shed	434	4/4/2017	Cutting Shed	470, 1.0	4.05	45	11
384.358D11A7B2	3/23/2015	Coulee	447	9/4/2019	Coulee	533, 1.5	4.45	86	19
		City of			Fourmile				
384.358D11A7D0	3/19/2015	Simms	315	4/8/2020	Creek	452, 0.8	5.06	137	27
				Mountain Whi	tefish				
		Cutting Shed			Cutting Shed				
384.3515DCBA9C	3/30/2015	Coulee	368	4/15/2019	Coulee	409, 0.7	4.05	41	10
		City of			City of				
384.358D11A7D1	3/19/2015	Simms	290	4/9/2018	Simms	338, 0.4	3.06	48	16
		Cutting Shed			Cutting Shed				
384.358D11A7FF	3/23/2015	Coulee	345	4/5/2019	Coulee	384, 0.5	4.04	38	9
Smith River									
				Rainbow Tr	out				
		Upper Sheep			Upper Sheep			_	
384.3515DC408E	10/7/2014	Creek	183	5/24/2016	Creek	272, 0.2	1.63	89	55
		Upper Sheep	105		Upper Sheep				
384.3515DC40B0	10/7/2014	Creek	180	7/7/2016	Creek	254	1.75	74	42

2349

2351 Table 24 – continued

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384.3515DC40B5 10/7/2014 Creek 201 5/24/2016 Creek 297, 0.2 1.63 86 53 384.3515DC40B3 10/7/2014 Creek 132 7/7/2016 Creek 295 0.12 8 63 384.3515DC40E3 10/7/2014 Creek 132 7/7/2016 Creek 185 1.75 53 30 384.3515DC4173 9/18/2014 Creek 427 9/24/2015 Creek 437, 0.7 1.02 10 10 384.3515DC4173 9/18/2014 Creek 356 9/24/2015 Creek 417, 0.8 1.02 64 45 384.3515DC4194 9/18/2014 Creek 246 9/24/2015 Creek 451, 0.43 1.02 64 62 384.3515DC4194 9/18/2014 Creek 257 9/24/2015 Creek 360, 0.2 1.02 43 42 384.3515DC4192 9/18/2014 Creek 257 9/24/2015 Creek 368, 0.5 1.02 89
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Blacktail
384.3515DDFA09 9/8/2014 Creek 295 9/13/2016 Creek 391, 0.6 2.02 97 48
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384.3515DDFA0C 9/9/2014 Creek 272 9/24/2015 Creek 330, 0.4 1.04 58 56
Blacktail Blacktail
304.3313000FA14 9/8/2014 Creek 198 9/24/2013 Creek 325, 0.5 1.04 124 119 Blacktail Blacktail
384.3515DDFA16 9/17/2014 Creek 290 9/24/2015 Creek 310 1.02 20 20

2353 Table 24 – continued

PT Date taged Subvatershed weight (mm, kg) Date recoursed recoursed Subvatershed recoursed length, recoursed Crewh (mm, kg) Statistiil 384.3515DDFA26 9/8/2014 Creek 22 9/24/2015 Creek 368.0.4 0.97 -5 -5 384.3515DDFA27 9/8/2014 Creek 231 9/13/2016 Creek 318.0.4 1.04 66 63 384.3515DDFA32 9/8/2014 Biacktail 236 9/24/2015 Creek 318.0.4 1.04 94 90 384.3515DDFA34 9/8/2014 Biacktail 236 9/24/2015 Creek 310.0.3 1.04 81 78 384.3515DDFA34 9/8/2014 Creek 229 9/24/2015 Creek 310.0.3 1.04 81 78 384.3515DFA34 9/8/2014 Creek 229 9/24/2015 Creek 310.0.3 1.04				Tagging			Recapture	Time to		Growth
Lagged Lagged Weight (mm, kg) recaptured (mm, kg) recaptured (mm, kg) recaptured (mm, kg) (mm, kg) (mm, kg) 384.3515DDFA26 9/8/2014 Creek 302 9/24/2015 Creek 308, 0.6 1.04 66 63 384.3515DDFA26 9/8/2014 Creek 231 9/13/2016 Creek 308, 0.4 1.04 94 90 384.3515DDFA26 9/8/2014 Creek 218 9/24/2015 Creek 30, 0.4 1.04 94 90 384.3515DDFA36 9/8/2014 Creek 218 9/24/2015 Creek 30, 0.4 1.04 81 78 384.3515DDFA36 9/8/2014 Creek 229 9/24/2015 Creek 30, 0.4 1.04 81 78 64 12 38	PIT	Date	Subwatershed	length,	Date	Subwatershed	length,	recapture	Growth	rate
Junit, Ag) Junk, Lg) Junk, Lg) Junk, Lg) Junk, Lg) 384.3515DDFA26 9/8/2014 Creek 323 9/24/2015 Creek, S73, 0.6 1.04 51 49 384.3515DDFA27 9/8/2014 Creek 302 9/24/2015 Creek, S68, 0.4 0.97 5 384.3515DDFA28 9/8/2014 Creek 302 9/24/2015 Creek 368, 0.6 1.04 66 63 384.3515DDFA32 9/8/2014 Creek 231 9/13/2016 Creek 30, 0.4 1.04 94 90 384.3515DDFA32 9/8/2014 Creek 218 9/24/2015 Creek 30, 0.4 1.04 81 78 384.3515DDFA43 9/8/2014 Creek 218 9/24/2015 Creek 318, 0.3 1.04 81 78 384.3515DDFA44 9/8/2014 Creek 229 9/24/2015 Creek 30, 0.4 1.04 71 68 384.3515DDFA44 9/8/2014 Creek 239 9/24/2015		tagged	tagged	weight	recaptured	recaptured	weight	(years)	(mm)	(mm/year)
384.3515DDFA26 9/8/2014 Diakkini Creek 373, 0.6 1.04 51 49 384.3515DDFA27 9/8/2014 Creek 322 9/2/2015 Creek 368, 0.4 0.97 -5 -5 384.3515DDFA27 9/8/2014 Creek 302 9/2/2015 Creek 368, 0.6 1.04 66 63 384.3515DDFA28 9/8/2014 Creek 32 9/13/2016 Creek 318, 0.4 2.02 86 43 384.3515DDFA32 9/8/2014 Creek 236 9/2/2015 Erecki 318, 0.3 1.04 91 95 384.3515DDFA40 9/8/2014 Creek 229 9/2/2/15 Erecki 310, 0.3 1.04 81 78 9/384.3515DDFA48 9/8/2014 Creek 279 9/2/2/15 Erecki 310, 0.3 1.04 81 78 9/384.3515DDFA48 9/8/2014 Creek 279 9/2/2/15 Creek 300, 0.4 1.04 71 68 384.3515DDFA5			Dlashtail	(mm, kg)		Dlaalstail	(mm, kg)			
364.3515DDFA20 95.2014 Creek 36.23 9.24.2013 East, and Creek 36.0, 00 1.04 51 49 384.3515DDFA27 9.82014 Creek 302 9/24/2015 Creek 368, 0.6 1.04 66 63 384.3515DDFA27 9.82014 Creek 231 9/13/2016 Creek 318, 0.4 1.04 94 90 384.3515DDFA32 9.82014 Creek 236 9/24/2015 Creek 330, 0.4 1.04 90 90 384.3515DDFA32 9.82014 Creek 223 9/24/2015 Creek 310, 0.3 1.04 91 90 384.3515DDFA43 9.82014 Creek 229 9/24/2015 Creek 310, 0.3 1.04 81 78 384.3515DDFA45 9.82014 Creek 257 9/24/2015 Creek 307, 0.3 1.04 51 49 384.3515DDFA45 9.82014 Creek 259 9/24/2015 Creek 307, 0.3 1.04 21 <td>384 3515DDEA 26</td> <td>0/8/2014</td> <td>Creek</td> <td>373</td> <td>0/24/2015</td> <td>Creek</td> <td>373 0.6</td> <td>1.04</td> <td>51</td> <td>40</td>	384 3515DDEA 26	0/8/2014	Creek	373	0/24/2015	Creek	373 0.6	1.04	51	40
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	564.5515DDFA20	9/0/2014	Cleek	323	9/24/2013	Blacktail	373, 0.0	1.04	51	49
Blacknii						Creek	368.0.4	0.97	-5	-5
384.3515DDFA27 9.8/2014 Creek Blacktanii 302 9.24/2015 Creek Blacktanii 384.3515DDFA2B 9.8/2014 Creek Creek 231 9.13/2016 Creek Blacktanii 310, 0.4 2.02 86 43 384.3515DDFA32 9.8/2014 Creek Blacktanii 236 9.24/2015 Creek Blacktanii 330, 0.4 1.04 94 90 384.3515DDFA40 9.8/2014 Creek Blacktanii 218 9.24/2015 Creek Blacktanii 310, 0.3 1.04 81 78 384.3515DDFA48 9.8/2014 Creek Blacktanii 29.24/2015 Creek Blacktanii 301, 0.3 1.04 81 78 384.3515DDFA48 9.8/2014 Creek Blacktanii 29.24/2015 Creek Blacktanii 307, 0.3 1.04 51 49 384.3515DDFA48 9.8/2014 Creek Blacktanii 29.24/2015 Creek Blacktanii 300, 0.4 1.04 71 68 384.3515DDFA54 9.8/2014 Creek Blacktanii 29.24/2015 Creek Blacktanii 312, 0.3 1.04 23 22 384.3515DDFA54 9.8/2014 Creek Blacktanii 312, 0.3			Blacktail			Blacktail	200, 011	0177	U	c
Blackail	384.3515DDFA27	9/8/2014	Creek	302	9/24/2015	Creek	368, 0.6	1.04	66	63
384.3515DDFA2B 9/8/2014 Creek 231 9/12/2016 Creek 318.0.4 2.02 86 43 384.3515DDFA32 9/8/2014 Creek 236 9/24/2015 Creek 330.0.4 1.04 94 99 384.3515DDFA40 9/8/2014 Creek 218 9/24/2015 Creek 318.0.3 1.04 81 78 384.3515DDFA43 9/8/2014 Creek 229 9/24/2015 Creek 300.0.3 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 257 9/24/2015 Creek 300.0.4 1.04 81 78 384.3515DDFA44 9/8/2014 Creek 257 9/24/2015 Creek 330.0.4 1.04 71 68 384.3515DDFA4E 9/8/2014 Creek 257 9/24/2015 Creek 378.0.6 1.02 48 47 384.3515DDFA54 9/17/2014 Creek 209 9/24/2015 Creek 378.0.6 1.02 48 47 384.3515DDFA54 9/8/2014 Creek 129 9/24/2015			Blacktail			Blacktail				
Blacktail Blacktail Blacktail Blacktail 384.3515DDFA40 9/2014 Creek 218 9/24/2015 Creek 330, 0.4 0.4 99 95 384.3515DDFA40 9/8/2014 Creek 218 9/24/2015 Creek 310, 0.3 1.04 99 95 384.3515DDFA43 9/8/2014 Creek 229 9/24/2015 Creek 290, 0.2 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 257 9/24/2015 Creek 269, 0.2 1.04 81 78 384.3515DDFA44 9/8/2014 Creek 259 9/24/2015 Creek 30, 0.4 1.04 71 68 384.3515DDFA54 9/17/2014 Creek 259 9/24/2015 Creek 30, 0.4 1.04 23 22 384.3515DDFA50 9/8/2014 Creek 175 9/24/2015 Creek 330, 0.4 0.97 58 60 384.3515DDFA50 9/8/2014 Creek 175 </td <td>384.3515DDFA2B</td> <td>9/8/2014</td> <td>Creek</td> <td>231</td> <td>9/13/2016</td> <td>Creek</td> <td>318, 0.4</td> <td>2.02</td> <td>86</td> <td>43</td>	384.3515DDFA2B	9/8/2014	Creek	231	9/13/2016	Creek	318, 0.4	2.02	86	43
384.3515DDFA32 9/8/2014 Creek 236 9/24/2015 Creek 30, 0.4 1.04 94 90 384.3515DDFA40 9/8/2014 Creek 218 9/24/2015 Creek 318, 0.3 1.04 99 95 384.3515DDFA43 9/8/2014 Creek 229 9/24/2015 Creek 310, 0.3 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 188 9/24/2015 Creek 269, 0.2 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 188 9/24/2015 Creek 269, 0.2 1.04 81 78 384.3515DDFA44 9/8/2014 Creek 29 9/24/2015 Creek 307, 0.3 1.04 21 49 384.3515DDFA55 9/8/2014 Creek 290 9/24/2015 Creek 378, 0.6 1.02 48 47 384.3515DDFA74 9/8/2014 Creek 290 9/24/2015 Creek 320, 0.3 1.04 23 22 384.3515DDFA75 9/8/2014 Creek 417 9/24/2015 </td <td></td> <td></td> <td>Blacktail</td> <td></td> <td></td> <td>Blacktail</td> <td></td> <td></td> <td></td> <td></td>			Blacktail			Blacktail				
Blacktail Blacktail Blacktail Blacktail Blacktail 384.3515DDFA43 9/8/2014 Creek 229 9/24/2015 Creek 310, 0.3 1.04 81 78 384.3515DDFA43 9/8/2014 Creek 129 9/24/2015 Creek 269, 0.2 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 188 9/24/2015 Creek 269, 0.2 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 259 9/24/2015 Creek 30, 0.4 1.04 71 68 384.3515DDFA4E 9/8/2014 Creek 259 9/24/2015 Creek 30, 0.4 1.04 71 68 384.3515DDFA5D 9/8/2014 Creek 30 9/24/2015 Creek 312, 0.3 1.04 23 22 384.3515DDFA5D 9/8/2014 Creek 279 9/24/2015 Creek 330, 0.4 1.04 104 100 384.3515DDFA74 9/8/2014 <t< td=""><td>384.3515DDFA32</td><td>9/8/2014</td><td>Creek</td><td>236</td><td>9/24/2015</td><td>Creek</td><td>330, 0.4</td><td>1.04</td><td>94</td><td>90</td></t<>	384.3515DDFA32	9/8/2014	Creek	236	9/24/2015	Creek	330, 0.4	1.04	94	90
384.3515DDFA40 9%/2014 Creek 218 9/2/2015 Creek 318, 0.3 1.04 99 95 384.3515DDFA43 9%/2014 Creek 229 9/2/2015 Creek 310, 0.3 1.04 81 78 384.3515DDFA48 9%/2014 Creek 229 9/24/2015 Creek 307, 0.3 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 257 9/24/2015 Creek 307, 0.3 1.04 51 49 384.3515DDFA48 9/8/2014 Creek 257 9/24/2015 Creek 307, 0.3 1.04 51 49 384.3515DDFA54 9/17/2014 Creek 259 9/24/2015 Creek 308, 0.4 1.04 71 68 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek 312, 0.3 1.04 23 22 384.3515DDFA7C 9/8/2014 Creek 177 9/24/2015 Creek 338, 0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek 417 9/24/2015 <td></td> <td></td> <td>Blacktail</td> <td></td> <td></td> <td>Blacktail</td> <td></td> <td></td> <td></td> <td></td>			Blacktail			Blacktail				
Blacktail Blacktail Blacktail Blacktail Blacktail 384.3515DDFA43 9k/2014 Creek 188 9/24/2015 Creek 269 0.2 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 257 9/24/2015 Creek 269 0.2 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 257 9/24/2015 Creek 307 0.3 1.04 51 49 384.3515DDFA48 9/8/2014 Creek 259 9/24/2015 Creek 307 0.3 1.04 71 68 384.3515DDFA54 9/17/2014 Creek 230 9/24/2015 Creek 279 0.2 1.04 104 100 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek 279 0.2 1.04 104 100 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek 339 0.4 0.97 <td< td=""><td>384.3515DDFA40</td><td>9/8/2014</td><td>Creek</td><td>218</td><td>9/24/2015</td><td>Creek</td><td>318, 0.3</td><td>1.04</td><td>99</td><td>95</td></td<>	384.3515DDFA40	9/8/2014	Creek	218	9/24/2015	Creek	318, 0.3	1.04	99	95
364-3515DDFA48 9/8/2014 Creek 229 9/2/2/2015 Creek 310, 0.3 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 188 9/2/2/2015 Creek 300, 0.3 1.04 81 78 384.3515DDFA48 9/8/2014 Creek 257 9/2/2/2015 Creek 300, 0.3 1.04 51 49 384.3515DDFA4E 9/8/2014 Creek 259 9/2/2/2015 Creek 330, 0.4 1.04 71 68 384.3515DDFA5D 9/8/2014 Creek 259 9/2/2/2015 Creek 378, 0.6 1.02 48 47 384.3515DDFA5D 9/8/2014 Creek 175 9/2/2/2015 Creek 312, 0.3 1.04 23 22 384.3515DDFA7 9/8/2014 Creek 175 9/2/2/2015 Creek 380, 0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek 175 9/2/2/2015 Creek 330, 0.4 1.04 23 22 384.3515DDFA86 9/8/2014 Creek 259 9/	204 25150004 42	0/0/2014	Blacktail	220	0/24/2015	Blacktail	210.02	1.04	0.1	70
384.3515DDFA48 9/8/2014 Creek Blacktail 188 9/24/2015 Creek Blacktail 269, 0.2 1.04 81 78 384.3515DDFA4A 9/8/2014 Creek Blacktail 257 9/24/2015 Creek Blacktail 30, 0.4 1.04 51 49 384.3515DDFA4E 9/8/2014 Creek Blacktail 259 9/24/2015 Creek Blacktail 30, 0.4 1.04 71 68 384.3515DDFA4E 9/8/2014 Creek Creek 330 9/24/2015 Creek Blacktail 378, 0.6 1.02 48 47 384.3515DDFA5D 9/8/2014 Creek Creek 290 9/24/2015 Creek Blacktail 312, 0.3 1.04 23 22 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek Blacktail 380, 0.9 1.04 23 22 384.3515DDFA7 9/8/2014 Creek 175 9/24/2015 Creek Blacktail 330, 0.4 1.02 76 75 384.3515DDFA81 9/8/2014 Creek 259 9/24/2015 Creek Blacktail 333, 0.4 1.02 76 75	384.3515DDFA43	9/8/2014	Creek	229	9/24/2015	Creek	310, 0.3	1.04	81	/8
364.3515DDFA4A 9/8/2014 Creek 257 9/24/2015 Creek 307,0.3 1.04 51 49 384.3515DDFA4A 9/8/2014 Creek 257 9/24/2015 Creek 300,0.4 1.04 71 68 384.3515DDFA4E 9/8/2014 Creek 259 9/24/2015 Creek 300,0.4 1.04 71 68 384.3515DDFA54 9/17/2014 Creek 259 9/24/2015 Creek 378,0.6 1.02 48 47 384.3515DDFA54 9/8/2014 Creek 290 9/24/2015 Creek 312,0.3 1.04 23 22 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek 38,0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek 259 9/24/2015 Creek 320,0.3 1.04 61 58 Blacktail Blacktail Blacktail Blacktail 100 100 100 100 100 100 100 100 100 100 100 100 100 10	384 3515DDEA 48	0/8/2014	Creek	188	0/24/2015	Greek	260 0 2	1.04	Q 1	78
384.3515DDFA4A 9/8/2014 Creek Blacktail 257 9/24/2015 Creek Blacktail 307, 0.3 1.04 51 49 384.3515DDFA4E 9/8/2014 Creek Blacktail 259 9/24/2015 Creek Blacktail 300, 0.4 1.04 71 68 384.3515DDFA5E 9/17/2014 Creek Blacktail 330 9/24/2015 Creek Blacktail 378, 0.6 1.02 48 47 384.3515DDFA5D 9/8/2014 Creek Blacktail 200 9/24/2015 Creek Blacktail 378, 0.6 1.04 23 22 384.3515DDFA7E 9/8/2014 Creek 290 9/24/2015 Creek 338, 0.4 0.97 58 60 Blacktail Blacktail 9/13/2016 Creek 338, 0.4 0.97 58 60 Blacktail 9/13/2016 Creek 338, 0.4 1.04 23 22 384.3515DDFA7C 9/8/2014 Creek 259 9/24/2015 Creek 330, 0.4 1.04 61 58 384.3515DDFA85 9/1/2014 Creek 257 </td <td>304.3313DDFA40</td> <td>9/0/2014</td> <td>Blacktail</td> <td>100</td> <td>9/24/2013</td> <td>Blacktail</td> <td>209, 0.2</td> <td>1.04</td> <td>01</td> <td>78</td>	304.3313DDFA40	9/0/2014	Blacktail	100	9/24/2013	Blacktail	209, 0.2	1.04	01	78
361.351.550.57.47.4 9/8/2014 Creek 259 9/24/2015 Creek 330, 0.4 1.04 71 68 384.35150.57.44 9/17/2014 Creek 259 9/24/2015 Creek 330, 0.4 1.04 71 68 384.35150.57.45 9/17/2014 Creek 330 9/24/2015 Creek 378, 0.6 1.02 48 47 384.35150.57.47.4 9/8/2014 Creek 290 9/24/2015 Creek 312, 0.3 1.04 23 22 384.35150.57.47.4 9/8/2014 Creek 175 9/24/2015 Creek 338, 0.4 0.97 58 60 384.35150.57.47.4 9/8/2014 Creek 175 9/24/2015 Creek 439, 0.9 1.04 23 22 384.35150.57.47.8 9/8/2014 Creek 259 9/24/2015 Creek 439, 0.9 1.04 61 58 384.35150.57.67.8 9/8/2014 Creek 257 9/24/2015 Creek 333, 0.4 1.02 76 75 384.35150.57.68 9/8/2014 Creek 257	384 3515DDFA4A	9/8/2014	Creek	257	9/24/2015	Creek	307 0 3	1.04	51	49
384.3515DDFA4E 9/8/2014 Creek Blacktail 259 9/24/2015 Creek Blacktail 330, 0.4 1.04 71 68 384.3515DDFA54 9/17/2014 Creek Blacktail 330 9/24/2015 Creek Blacktail 378, 0.6 1.02 48 47 384.3515DDFA5D 9/8/2014 Creek Blacktail 290 9/24/2015 Creek Blacktail 312, 0.3 1.04 23 22 384.3515DDFA74 9/8/2014 Creek Blacktail 175 9/24/2015 Creek Blacktail 312, 0.3 1.04 04 100 384.3515DDFA7C 9/8/2014 Creek 417 9/24/2015 Creek Blacktail 338, 0.4 0.97 58 60 384.3515DDFA81 9/8/2014 Creek 257 9/24/2015 Creek 330, 0.3 1.04 61 58 384.3515DDFA83 9/17/2014 Creek 257 9/24/2015 Creek 330, 0.4 1.02 76 75 384.3515DFA86 9/8/2014 Creek 254 9/24/2015 Creek 315, 0.4 1.04 99 95 384.3515DFA	504.551500111411	9/0/2014	Blacktail	237	<i>)/24/2015</i>	Blacktail	507, 0.5	1.04	51	-12
Blacktail Blacktail Blacktail Blacktail Blacktail 384.3515DDFA54 9/17/2014 Creek 330 9/24/2015 Creek 378,0.6 1.02 48 47 384.3515DDFA5D 9/8/2014 Creek 290 9/24/2015 Creek 312,0.3 1.04 23 22 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek 279,0.2 1.04 104 100 384.3515DDFA7C 9/8/2014 Creek 175 9/24/2015 Creek 338,0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek 417 9/24/2015 Creek 330,0.4 1.04 23 22 384.3515DDFA81 9/8/2014 Creek 259 9/24/2015 Creek 320,0.3 1.04 61 58 384.3515DDFA85 9/8/2014 Creek 257 9/24/2015 Creek 333,0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek 254 9/24/2015 Creek 353,0.4 1.04 99 9	384.3515DDFA4E	9/8/2014	Creek	259	9/24/2015	Creek	330, 0.4	1.04	71	68
384.3515DDFA54 9/17/2014 Creek Blacktail 330 9/24/2015 Creek Blacktail 378, 0.6 1.02 48 47 384.3515DDFA5D 9/8/2014 Creek Creek 290 9/24/2015 Creek Blacktail 312, 0.3 1.04 23 22 384.3515DDFA74 9/8/2014 Creek Blacktail 175 9/24/2015 Creek Blacktail 279, 0.2 1.04 004 100 384.3515DDFA7C 9/8/2014 Creek Creek 417 9/24/2015 Creek Blacktail 380, 0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek Creek 417 9/24/2015 Creek Blacktail 320, 0.3 1.04 61 58 384.3515DDFA81 9/8/2014 Creek 257 9/24/2015 Creek Blacktail 330, 0.4 1.02 76 75 384.3515DDFA83 9/17/2014 Creek 257 9/24/2015 Creek Blacktail 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek 257 9/24/2015 Creek Blacktail 350, 0.4 1.04 99 95	001000000000000000000000000000000000000	<i>y</i> , o, <u>2</u> 01.	Blacktail	-07	<i>,,_,,_</i> ,,_,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Blacktail	220,011	1101	71	00
Blacktail Blacktail 384.3515DDFA5D 9/8/2014 $Creek$ Blacktail 290 9/24/2015 $Creek$ Blacktail 312, 0.3 1.04 23 22 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 $Creek$ Blacktail 279, 0.2 1.04 104 100 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek Blacktail 338, 0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek 417 9/24/2015 Creek Blacktail 338, 0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek 259 9/24/2015 Creek Blacktail 330, 0.4 1.02 76 75 384.3515DDFA83 9/17/2014 Creek 257 9/24/2015 Creek Blacktail 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek 254 9/24/2015 Creek 312, 0.4 1.04 226 217 384.3515DDFA87 9/9/2014 Creek 254 9/24/2015 Creek 353, 0.4 1.04 53	384.3515DDFA54	9/17/2014	Creek	330	9/24/2015	Creek	378, 0.6	1.02	48	47
384.3515DDFA5D 9/8/2014 Creek Blacktatil 312, 0.3 1.04 23 22 384.3515DDFA74 9/8/2014 Creek Creek 175 9/24/2015 Creek Blacktail 312, 0.3 1.04 104 100 384.3515DDFA74 9/8/2014 Creek 175 9/24/2015 Creek Blacktail 238, 0.4 0.97 58 60 384.3515DDFA7C 9/8/2014 Creek Blacktail 417 9/24/2015 Creek Creek 339, 0.9 1.04 23 22 384.3515DDFA81 9/8/2014 Creek 257 9/24/2015 Creek 320, 0.3 1.04 61 58 384.3515DDFA83 9/17/2014 Creek 257 9/24/2015 Creek 320, 0.3 1.04 226 217 384.3515DDFA86 9/8/2014 Creek 185 9/24/2015 Creek 353, 0.4 1.04 99 9 384.3515DDFA87 9/9/2014 Creek 234 9/24/2015 Creek 353, 0.4 1.04 99 9 384.3515DDFA9A 9/8/2014 Creek 234 9/24/2015			Blacktail			Blacktail	,			
BlacktailBlacktail384.3515DDFA749/8/2014Creek1759/24/2015Creek279, 0.21.04104100Blacktail9/13/2016Creek338, 0.40.975860384.3515DDFA7C9/8/2014Creek4179/24/2015Creek439, 0.91.042322384.3515DDFA819/8/2014Creek2599/24/2015Creek320, 0.31.046158384.3515DDFA839/17/2014Creek2579/24/2015Creek333, 0.41.027675BlacktailBlacktailBlacktailBlacktailBlacktail1.04226217384.3515DDFA869/8/2014Creek1859/24/2015Creek411, 0.71.04226217384.3515DDFA879/9/2014Creek2349/24/2015Creek353, 0.41.049995384.3515DDFA989/8/2014Creek2349/24/2015Creek287, 0.31.045351384.3515DDFA449/17/2014Creek2979/13/2016Creek356, 0.42.015829384.3515DDFAA69/8/2014Creek2979/13/2016Creek315, 0.41.0410297384.3515DDFAA69/17/2014Creek2139/24/2015Creek4061.02100100384.3515DDFAA69/8/2014Creek2139/24/2015Creek305, 0.31.0	384.3515DDFA5D	9/8/2014	Creek	290	9/24/2015	Creek	312, 0.3	1.04	23	22
$\begin{array}{cccccccccccccccccccccccccccccccccccc$			Blacktail			Blacktail				
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	384.3515DDFA74	9/8/2014	Creek	175	9/24/2015	Creek	279, 0.2	1.04	104	100
$\begin{array}{c c c c c c c c c c c c c c c c c c c $						Blacktail				
384.3515DDFA7C 9/8/2014 Creek 417 9/24/2015 Creek 439, 0.9 1.04 23 22 384.3515DDFA81 9/8/2014 Creek 259 9/24/2015 Creek 320, 0.3 1.04 61 58 384.3515DDFA81 9/8/2014 Creek 257 9/24/2015 Creek 330, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek 257 9/24/2015 Creek 411, 0.7 1.04 226 217 384.3515DDFA86 9/8/2014 Creek 254 9/24/2015 Creek 411, 0.7 1.04 226 217 384.3515DDFA87 9/9/2014 Creek 254 9/24/2015 Creek 353, 0.4 1.04 99 95 384.3515DDFA9A 9/8/2014 Creek 254 9/24/2015 Creek 287, 0.3 1.04 53 51 384.3515DDFA9A 9/9/2014 Creek 234 9/24/2015 Creek 287, 0.3 1.04 53 51 384.3515DDFAA4 9/9/2014 Creek 297 9/13/					9/13/2016	Creek	338, 0.4	0.97	58	60
384.3515DDFA/C 9/8/2014 Creek 417 9/24/2015 Creek 439,0.9 1.04 23 22 384.3515DDFA81 9/8/2014 Creek 259 9/24/2015 Creek 320,0.3 1.04 61 58 384.3515DDFA83 9/17/2014 Creek 257 9/24/2015 Creek 333,0.4 1.02 76 75 Blacktail Blacktail Blacktail 0 0.3 1.04 22 217 384.3515DDFA86 9/8/2014 Creek 185 9/24/2015 Creek 333,0.4 1.02 76 75 Blacktail Blacktail Blacktail Blacktail 0 0 95 384.3515DDFA87 9/9/2014 Creek 254 9/24/2015 Creek 353,0.4 1.04 99 95 384.3515DDFA98 9/9/2014 Creek 234 9/24/2015 Creek 356,0.4 2.01 58 29 Blacktail Blacktail Blacktail Blacktail 0 00 100 100 384.3515DDFAA6 9/8/20	204 2515000470	0/0/2014	Blacktail	417	0/04/0015	Blacktail	120.00	1.04	22	22
384.3515DDFA81 9/8/2014 Creek Blacktail 259 9/24/2015 Creek Blacktail 320, 0.3 1.04 61 58 384.3515DDFA83 9/17/2014 Creek Blacktail 257 9/24/2015 Creek Blacktail 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek Blacktail 185 9/24/2015 Creek Blacktail 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek Creek 254 9/24/2015 Creek Blacktail 353, 0.4 1.04 99 95 384.3515DDFA97 9/9/2014 Creek Creek 234 9/24/2015 Creek Blacktail 353, 0.4 1.04 99 95 384.3515DDFA98 9/8/2014 Creek Creek 234 9/24/2015 Creek Blacktail 356, 0.4 2.01 58 29 384.3515DDFAA6 9/9/2014 Creek Creek 205 9/24/2015 Creek Blacktail 315, 0.4 1.04 102 97 384.3515DDFAA6 9/8/2014 Creek Blacktail 213 9/24/2015 Creek Blacktail 302, 0.3 1.04 74	384.3515DDFA/C	9/8/2014	Creek	417	9/24/2015	Creek	439, 0.9	1.04	23	22
384.3515DDFA81 9/8/2014 Creek 259 9/24/2013 Creek 320, 0.3 1.04 01 38 384.3515DDFA83 9/17/2014 Creek 257 9/24/2015 Creek 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek 185 9/24/2015 Creek 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek 185 9/24/2015 Creek 353, 0.4 1.04 99 95 384.3515DDFA87 9/9/2014 Creek 254 9/24/2015 Creek 287, 0.3 1.04 53 51 384.3515DDFA9A 9/8/2014 Creek 234 9/24/2015 Creek 287, 0.3 1.04 53 51 384.3515DDFA9B 9/9/2014 Creek 237 9/13/2016 Creek 356, 0.4 2.01 58 29 384.3515DDFAA6 9/8/2014 Creek 305 9/24/2015 Creek 406 1.02 102 100 384.3515DDFAA6 9/8/2014 Creek 305 9/24/2015 </td <td>29/ 2515DDEA 91</td> <td>0/8/2014</td> <td>Graak</td> <td>250</td> <td>0/24/2015</td> <td>Graak</td> <td>220 0 2</td> <td>1.04</td> <td>61</td> <td>59</td>	29/ 2515DDEA 91	0/8/2014	Graak	250	0/24/2015	Graak	220 0 2	1.04	61	59
384.3515DDFA83 9/17/2014 Creek Blacktail 257 9/24/2015 Creek Blacktail 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek Blacktail 185 9/24/2015 Creek Blacktail 333, 0.4 1.02 76 75 384.3515DDFA86 9/8/2014 Creek Blacktail 185 9/24/2015 Creek Blacktail 411, 0.7 1.04 226 217 384.3515DDFA87 9/9/2014 Creek Creek 254 9/24/2015 Creek Blacktail 353, 0.4 1.04 99 95 384.3515DDFA9A 9/8/2014 Creek Blacktail 234 9/24/2015 Creek Blacktail 287, 0.3 1.04 53 51 384.3515DDFA9B 9/9/2014 Creek Blacktail 297 9/13/2016 Creek Blacktail 356, 0.4 2.01 58 29 384.3515DDFAA6 9/8/2014 Creek Blacktail 305 9/24/2015 Creek Blacktail 315, 0.4 1.04 102 97 384.3515DDFAA6 9/8/2014 Creek Creek 213 9/24/2015 Creek Blacktail 302, 0.3 1.04 74	504.5515DDFA01	9/8/2014	Blacktail	239	9/24/2013	Blacktail	520, 0.5	1.04	01	58
384.3515DDFA86 9/8/2014 Creek 185 9/24/2015 Creek 411, 0.7 1.04 226 217 384.3515DDFA86 9/8/2014 Creek 185 9/24/2015 Creek 353, 0.4 1.04 226 217 384.3515DDFA87 9/9/2014 Creek 254 9/24/2015 Creek 353, 0.4 1.04 99 95 Blacktail Blacktail Blacktail Blacktail 104 53 51 384.3515DDFA9A 9/9/2014 Creek 254 9/24/2015 Creek 353, 0.4 1.04 53 51 384.3515DDFA9A 9/8/2014 Creek 297 9/13/2016 Creek 356, 0.4 2.01 58 29 Blacktail Blacktail Blacktail 102 100 102 100 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 302, 0.3 1.04 74 71	384 3515DDFA83	9/17/2014	Creek	257	9/24/2015	Creek	333 04	1.02	76	75
384.3515DDFA86 9/8/2014 Creek 185 9/24/2015 Creek 411, 0.7 1.04 226 217 384.3515DDFA87 9/9/2014 Creek 254 9/24/2015 Creek 353, 0.4 1.04 99 95 384.3515DDFA9A 9/8/2014 Creek 234 9/24/2015 Creek 287, 0.3 1.04 53 51 384.3515DDFA9A 9/8/2014 Creek 234 9/24/2015 Creek 287, 0.3 1.04 53 51 384.3515DDFA9B 9/9/2014 Creek 297 9/13/2016 Creek 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek 305 9/24/2015 Creek 406 1.02 102 100 Blacktail Blacktail Blacktail Blacktail 102 97 97 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 Blacktail Blacktail Blacktail Blacktail 1.04 102 97	504.5515001105	<i>)/1//201</i> 4	Blacktail	237	<i>)</i> /24/2015	Blacktail	555, 0.4	1.02	70	15
Blacktail Blacktail Blacktail 384.3515DDFA87 9/9/2014 Creek Blacktail 254 9/24/2015 Creek Blacktail 353, 0.4 1.04 99 95 384.3515DDFA9A 9/8/2014 Creek Blacktail 234 9/24/2015 Creek Blacktail 287, 0.3 1.04 53 51 384.3515DDFA9B 9/9/2014 Creek Creek 297 9/13/2016 Creek Creek Blacktail 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek Creek 297 9/13/2016 Creek Creek Blacktail 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek Creek 305 9/24/2015 Creek Blacktail 315, 0.4 1.04 102 97 384.3515DDFAA6 9/8/2014 Creek Creek 213 9/24/2015 Creek Blacktail 302, 0.3 1.04 74 71 384.3515DDFAA6 9/9/2014 Creek Creek 229 9/24/2015 Creek Creek 302, 0.3 1.04 74 71 Blacktaiil 9/13/2016 Cr	384.3515DDFA86	9/8/2014	Creek	185	9/24/2015	Creek	411.0.7	1.04	226	217
384.3515DDFA87 9/9/2014 Creek 254 9/24/2015 Creek 353, 0.4 1.04 99 95 384.3515DDFA9A 9/8/2014 Creek 234 9/24/2015 Creek 287, 0.3 1.04 53 51 384.3515DDFA9A 9/8/2014 Creek 297 9/13/2016 Creek 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek 305 9/24/2015 Creek 406 1.02 102 100 Blacktail Blacktail Blacktail Blacktail 102 100 102 100 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 302, 0.3 1.04 74 71 384.3515DDFAA6 9/9/2014 Creek 229 9/24/2015 Creek 302, 0.3 1.04 74 71 Blacktail 9/13/2016 Creek 325, 0.3 0.97 23 24 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74 <td></td> <td></td> <td>Blacktail</td> <td></td> <td></td> <td>Blacktail</td> <td>,</td> <td></td> <td></td> <td></td>			Blacktail			Blacktail	,			
Blacktail Blacktail Blacktail 384.3515DDFA9A 9/8/2014 Creek Blacktail 234 9/24/2015 Creek Blacktail 287, 0.3 1.04 53 51 384.3515DDFA9B 9/9/2014 Creek Blacktail 297 9/13/2016 Creek Blacktail 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek Blacktail 305 9/24/2015 Creek 406 1.02 102 100 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 74 97 384.3515DDFAA6 9/9/2014 Creek 213 9/24/2015 Creek 302, 0.3 1.04 74 71 384.3515DDFAAA 9/9/2014 Creek 229 9/24/2015 Creek 302, 0.3 1.04 74 71 384.3515DDFAAA 9/9/2014 Creek 229 9/13/2016 Creek 325, 0.3 0.97 23 24 384.3515DDFAAA 9/9/2014 Creek Blacktail 224 9/13/2016 Creek Blacktail 373, 0.6 2.01	384.3515DDFA87	9/9/2014	Creek	254	9/24/2015	Creek	353, 0.4	1.04	99	95
384.3515DDFA9A 9/8/2014 Creek Blacktail 234 9/24/2015 Creek Blacktail 287, 0.3 1.04 53 51 384.3515DDFA9B 9/9/2014 Creek Blacktail 297 9/13/2016 Creek Blacktail 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek Blacktail 305 9/24/2015 Creek Blacktail 406 1.02 102 100 384.3515DDFAA6 9/8/2014 Creek Blacktail 213 9/24/2015 Creek Blacktail 315, 0.4 1.04 102 97 384.3515DDFAA6 9/9/2014 Creek Creek 229 9/24/2015 Creek Blacktail 302, 0.3 1.04 74 71 384.3515DDFAAA 9/9/2014 Creek Creek 229 9/24/2015 Creek Blacktail 302, 0.3 1.04 74 71 384.3515DDFAAE 9/9/2014 Creek Blacktail 224 9/13/2016 Creek Blacktail 373, 0.6 2.01 150 74			Blacktail			Blacktail				
Blacktail Blacktail 384.3515DDFA9B 9/9/2014 Creek 297 9/13/2016 Creek 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek 305 9/24/2015 Creek 406 1.02 102 100 Blacktail Blacktail Blacktail Blacktail 0 0 102 97 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 Blacktail Blacktail Blacktail 0 0 100 97 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 Blacktail Blacktail 0	384.3515DDFA9A	9/8/2014	Creek	234	9/24/2015	Creek	287, 0.3	1.04	53	51
384.3515DDFA9B 9/9/2014 Creek 297 9/13/2016 Creek 356, 0.4 2.01 58 29 384.3515DDFAA4 9/17/2014 Creek 305 9/24/2015 Creek 406 1.02 102 100 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 Blacktail Blacktail 9/24/2015 Creek 302, 0.3 1.04 74 71 Blacktail 9/13/2016 Creek 325, 0.3 0.97 23 24 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74			Blacktail			Blacktail				
Blacktail Blacktail Blacktail 384.3515DDFAA4 9/17/2014 Creek 305 9/24/2015 Creek 406 1.02 102 100 Blacktail Blacktail Blacktail Blacktail 102 97 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 Blacktail Blacktail Blacktail 102 97 100 100 100 97 384.3515DDFAAA 9/9/2014 Creek 229 9/24/2015 Creek 302, 0.3 1.04 74 71 384.3515DDFAAA 9/9/2014 Creek 229 9/13/2016 Creek 325, 0.3 0.97 23 24 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74	384.3515DDFA9B	9/9/2014	Creek	297	9/13/2016	Creek	356, 0.4	2.01	58	29
384.3515DDFAA4 9/1//2014 Creek 305 9/24/2015 Creek 406 1.02 102 100 Blacktail Blacktail Blacktail Blacktail Blacktail 102 97 384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 315, 0.4 1.04 102 97 384.3515DDFAA6 9/9/2014 Creek 229 9/24/2015 Creek 302, 0.3 1.04 74 71 Blacktail 9/13/2016 Creek 325, 0.3 0.97 23 24 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74			Blacktail	2 2 7		Blacktail	10.4		100	100
Blacktail Blacktail Blacktail Blacktail Blacktail Image: Second	384.3515DDFAA4	9/1//2014	Creek	305	9/24/2015	Creek	406	1.02	102	100
384.3515DDFAA6 9/8/2014 Creek 213 9/24/2015 Creek 313, 0.4 1.04 102 9/7 384.3515DDFAAA 9/9/2014 Creek 229 9/24/2015 Creek 302, 0.3 1.04 74 71 Blacktail 9/13/2016 Creek 325, 0.3 0.97 23 24 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74		0/9/2014	Blacktail	212	0/24/2015	Blacktail	215 0 4	1.04	102	07
384.3515DDFAAA 9/9/2014 Creek 229 9/24/2015 Creek 302, 0.3 1.04 74 71 Blacktail 9/13/2016 Creek 325, 0.3 0.97 23 24 Blacktail Blacktail 81 100 100 74 71 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74 Blacktail Blacktail Blacktail 100 150 74	584.5515DDFAA0	9/8/2014	Placktail	215	9/24/2013	Disalstail	515, 0.4	1.04	102	97
Side.3515DDFAAR 9/9/2014 Creek 22.9 9/24/2013 Creek 302, 0.3 1.04 74 71 Blacktail 9/13/2016 Creek 325, 0.3 0.97 23 24 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74 Blacktail Blacktail Blacktail Blacktail 150 74	384 3515DDEA A A	0/0/2014	Creek	220	0/24/2015	Creek	302 0 3	1.04	74	71
9/13/2016 Creek 325, 0.3 0.97 23 24 Blacktail Blacktail 813/2016 Creek 373, 0.6 2.01 150 74 Blacktail Blacktail Blacktail 81 81 81 150 74	JUTIJJJJJJDDFAAA	JI JI 2014	CICCK	227	JI 24/2013	Blacktail	502, 0.5	1.04	/4	/ 1
Blacktail Blacktail Blacktail 384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74 Blacktail Blacktail Blacktail Blacktail Blacktail 150 74					9/13/2016	Creek	325 03	0.97	23	24
384.3515DDFAAE 9/9/2014 Creek 224 9/13/2016 Creek 373, 0.6 2.01 150 74 Blacktail Blacktail Blacktail Blacktail Blacktail Blacktail Blacktail Blacktail Creek 373, 0.6 2.01 150 74			Blacktail		2,12,2010	Blacktail	020,000	0.21		- •
Blacktail Blacktail	384.3515DDFAAE	9/9/2014	Creek	224	9/13/2016	Creek	373, 0.6	2.01	150	74
			Blacktail			Blacktail	,			
384.3515DDFABB 9/17/2014 Creek 414 9/24/2015 Creek 424, 0.7 1.02 10 10	384.3515DDFABB	9/17/2014	Creek	414	9/24/2015	Creek	424, 0.7	1.02	10	10

2355 Table 24 – continued

			Tagging			Recapture	Time to		Growth
PIT	Date	Subwatershed	length,	Date	Subwatershed	length,	recapture	Growth	rate
	tagged	tagged	weight	recaptured	recaptured	weight	(years)	(mm)	(mm/year)
			(mm, kg)			(mm, kg)	0		()/
201 251 50 52 1 22	0/10/2014	Middle Sheep	102		Upper Sheep	2.11	1.00	50	22
384.3515DE2A33	9/10/2014	Creek	183	7/7/2016	Creek	241	1.82	58	32
204 25150524 40	0/10/2014	Middle Sheep	155	4/14/2017	Blacktail	215	2.50	1.00	(2)
384.3515DE2A40	9/10/2014	Creek Middle Sheen	155	4/14/2017	Creek	315	2.59	160	62
294 2515DE2 4 40	0/10/2014	Creak	212	7/7/2016	Opper Sneep	254	1.92	4.1	22
384.3313DE2A49	9/10/2014	Creek Middle Sheen	213	////2016	Urner Sheen	254	1.82	41	22
294 2515DE2461	0/10/2014	Crook	145	7/7/2016	Opper Sneep	246	1.92	102	56
364.3313DE2A01	9/10/2014	Middle Sheen	143	////2010	Upper Sheep	240	1.62	102	50
384 3515DE2A0C	0/10/2014	Creek	272	7/7/2016	Creek	202	1.82	20	11
564.5515DE2A9C	9/10/2014	Middle Sheen	212	////2010	Blacktail	292	1.62	20	11
384 3515DE2AB7	0/11/2014	Creek	142	0/13/2016	Creek	330.03	2.01	199	04
564.5515DE2AD7	9/11/2014	Middle Sheen	142	9/13/2010	Upper Sheen	550, 0.5	2.01	100	24
384 3515DE2BB0	9/17/2014	Creek	165	7/7/2016	Creek	282	1.81	117	65
504.5515DE2DD0)/1//2014	CICCK	105	////2010	Cottonwood	282	1.01	117	05
				3/23/2017	Creek	279	0.71	-3	-4
		Middle Sheen		3/23/2017	Unner Sheen	21)	0.71	-5	
384 3515DE2BE9	9/17/2014	Creek	142	5/24/2016	Creek	254 0 2	1 68	112	66
50 1.55 15D EEDE)	<i><i><i>M</i>1<i>M</i>2011</i></i>	Middle Sheen	112	5/2 1/2010	Unner Sheen	23 1, 0.2	1.00	112	00
384 3515DE2C13	9/17/2014	Creek	185	7/7/2016	Creek	277	1.81	91	51
384.3515DE9796	10/15/2014	Moose Creek	152	8/29/2015	Moose Creek	196.0.1	0.87	43	50
00110010020,770	10/10/2011		102	0/2//2010	Upper Sheep	1, 0, 0, 1	0107	10	20
384.3515DE97C7	10/15/2014	Moose Creek	130	7/7/2016	Creek	262	1.73	132	76
					Blacktail				
384.3515DE9804	10/15/2014	Moose Creek	236	9/24/2015	Creek	267.0.2	0.94	30	32
					Upper Sheep				
384.3515DE9812	10/15/2014	Moose Creek	175	7/7/2016	Creek	249	1.73	74	43
384.3515DE9841	10/15/2014	Moose Creek	234	8/29/2015	Moose Creek	244, 0.1	0.87	10	12
		Middle Sheep			Middle Sheep	*			
384.3515DE9A62	10/9/2014	Creek	117	8/29/2015	Creek	201, 0.1	0.89	84	94
		Rock Springs			Rock Springs				
384.3515DE9B95	10/13/2014	Creek	234	3/22/2017	Creek	386, 0.2	2.44	152	62
					Cottonwood				
384.3515DE9C29	10/15/2014	Moose Creek	175	3/23/2017	Creek	269, 0.2	2.44	94	39
384.3515DE9CC6	10/15/2014	Moose Creek	150	8/29/2015	Moose Creek	196, 0.1	0.87	46	52
					Blacktail				
384.3515DE9CE6	10/15/2014	Moose Creek	102	9/13/2016	Creek	274, 0.2	1.92	173	90
384.3515DE9EAD	10/20/2014	Moose Creek	175	10/24/2016	Two Creek	297, 0.3	2.01	122	61
384.3515DE9ED1	10/29/2014	Moose Creek	137	8/29/2015	Moose Creek	183	0.83	46	55
		Lower Sheep			Blacktail				
384.358D11A8C9	10/21/2014	Creek	211	9/24/2015	Creek	257, 0.2	0.93	46	49
384.358D11A9E8	10/29/2014	Moose Creek	183	8/29/2015	Moose Creek	211, 0.1	0.83	28	34
384.358D11A9F1	10/29/2014	Moose Creek	155	10/24/2016	Two Creek	290, 0.2	1.99	135	68
384.358D11AA24	10/29/2014	Moose Creek	163	8/29/2015	Moose Creek	203, 0.1	0.83	41	49
					Upper Sheep				
384.358D11AA39	10/29/2014	Moose Creek	221	7/7/2016	Creek	272	1.69	51	30
3D6.0017F7A28A	10/15/2015	Two Creek	361, 0.6	10/24/2016	Two Creek	373, 0.5	1.03	13	12
3D6.0017F7A28B	10/15/2015	Two Creek	333	10/17/2016	Two Creek	368, 0.5	1.01	36	35
3D6.0017F7A364	10/15/2015	Two Creek	338	10/24/2016	Two Creek	404, 0.7	1.03	66	64
3D6.001/F/A3/D	10/15/2015	Two Creek	2/4	10/17/2016	Two Creek	338, 0.4	1.01	64	63
3D6.00182C0410	10/15/2015	Two Creek	315	10/18/2016	Two Creek	361, 0.6	1.01	46	45
3D6.00182C0420	10/15/2015	Two Creek	218	10/18/2016	Two Creek	305, 0.3	1.01	86	85
3D6.00182C0423	10/15/2015	Two Creek	226	10/17/2016	Two Creek	558, 0.4	1.01	112	111
3D6.00182C042B	10/15/2015	Two Creek	305	10/1//2016	Two Creek	331, 0.4 201 0 C	1.01	40 <1	45
300.0018200438	10/13/2015	I wo Creek	550	10/23/2016	I WO Creek	391, 0.0	1.05	01	39
2356 Table 24 – continued

			Tagging			Recapture	T . (
DIT	Date	Subwatershed	length,	Date	Subwatershed	length,	Time to	Growth	Growth
PIT	tagged	tagged	weight	recaptured	recaptured	weight	recapture	(mm)	rate
			(mm, kg)	<u>-</u>	<u>r</u>	(mm, kg)	(years)	()	(mm/year)
3D6 00182C045E	10/15/2015	Two Creek	307	10/17/2016	Two Creek	338.04	1.01	30	30
3D6 00182C045E	10/15/2015	Two Creek	330	10/17/2016	Two Creek	323 0 3	1.01	-8	-8
3D6.00182C0403	10/15/2015	Two Creek	230	10/17/2016	Two Creek	305 0 3	1.01	-0	-0
2D6.00182C0470	10/15/2015	Two Creek	239	10/17/2016	Two Creek	303, 0.3	1.01	00	00
3D0.00182C047C	10/15/2015	Two Creek	251	10/17/2010	Two Creek	323, 0.3	1.01	91	91
3D6.00182C0490	10/15/2015	Two Creek	213	10/25/2016	Two Creek	287, 0.3	1.05	74	12
3D6.00182C04A3	10/15/2015	Two Creek	368	10/1//2016	Two Creek	384, 0.5	1.01	15	15
3D6.00182C04A7	10/15/2015	Two Creek	345	10/18/2016	Two Creek	409, 0.8	1.01	64	63
3D6.00182C04AF	10/15/2015	Two Creek	361	10/17/2016	Two Creek	371, 0.6	1.01	10	10
		Upper Sheep			Cottonwood				
3D6.00182C051C	5/24/2016	Creek	236, 0.1	3/23/2017	Creek	264, 0.2	0.83	28	34
		Upper Sheep			Upper Sheep				
3D6.00182C053F	5/24/2016	Creek	193, 0.1	7/7/2016	Creek	211	0.12	18	147
		Upper Sheep			Cottonwood				
3D6.00182C0544	5/24/2016	Creek	211, 0.1	3/23/2017	Creek	221, 0.1	0.83	10	12
		Cottonwood	,		Cottonwood	,			
3D6.00182C0553	5/25/2016	Creek	391.0.6	3/23/2017	Creek	452.0.9	0.83	61	74
520.0010200555	5/25/2010	Cottonwood	591, 0.0	5/25/2011	Cottonwood	132, 019	0.05	01	, 1
3D6 00182C056D	5/25/2016	Creek	363 0 5	6/23/2016	Creek	373 0.6	0.08	10	128
3D0.00102C030D	5/25/2010	CIUK	505, 0.5	0/23/2010	Cottonwood	575, 0.0	0.00	10	120
				2/22/2017	Cutoliwood	200	0.75	25	24
2DC 00102C05 45	10/15/2015		259	3/23/2017	Стеек	399	0.75	25	54
3D6.00182C05A5	10/15/2015	Two Creek	358	10/18/2016	Two Creek	399, 0.6	1.01	41	40
3D6.00182C05F8	10/15/2015	Two Creek	206	10/17/2016	Two Creek	310, 0.3	1.03	104	103
3D6.00182C0609	10/15/2015	Two Creek	249	10/24/2016	Two Creek	318, 0.3	1.03	69	67
3D6.00182C0624	10/15/2015	Two Creek	315	10/24/2016	Two Creek	361, 0.5	1.03	46	45
3D6.00182C062D	10/15/2015	Two Creek	208	10/24/2016	Two Creek	312, 0.3	1.03	104	101
3D6.00182C0635	10/15/2015	Two Creek	226	10/17/2016	Two Creek	318, 0.3	1.01	91	91
				6/7/2017	Two Creek	343	0.67	25	38
		Cottonwood			Blacktail				
3D6.00183A1BE5	6/23/2016	Creek	419, 0.9	8/19/2016	Creek	419	0.16	0	0
			- ,		Cottonwood				
				3/23/2017	Creek	429.0.8	0.59	10	17
				Brown Troi	it Creek	129, 0.0	0.57	10	17
		Blacktail		Diown 1101	" Blacktail				
38// 3515DC/163	0/18/2014	Creek	315	9/24/2015	Creek	404 07	1.02	80	88
304.3313DC4103	9/16/2014	Disalitail	515	9/24/2013	Diadrad	404, 0.7	1.02	09	88
294 2515004202	0/17/2014	Creak	207	0/24/2015	Creak	296 0.9	1.02	70	77
384.3515DC4202	9/1//2014	Creek	307	9/24/2015	Creek	380, 0.8	1.02	19	11
204 251 5DDE 4 50	0/0/2014	Blacktall	215	0/04/0015	Blacktail	201.0.6	1.04		(2)
384.3515DDFA50	9/8/2014	Creek	315	9/24/2015	Creek	381, 0.6	1.04	66	63
					Blacktail				
				3/24/2016	Creek	399, 0.8	0.50	18	36
		Rock Springs			Rock Springs				
384.3515DE9A00	10/13/2014	Creek	361	3/22/2017	Creek	462, 0.9	2.44	102	42
		Lower Sheep			Blacktail				
384.3515DE9EBA	10/21/2014	Creek	330	3/24/2016	Creek	424, 0.8	1.42	94	66
3D6.0017F7A226	10/15/2015	Two Creek	386	10/17/2016	Two Creek	404, 0.6	1.01	18	18
3D6.0017F7A24F	10/15/2015	Two Creek	249	10/17/2016	Two Creek	330, 0.4	1.01	81	81
3D6.0017F7A39D	10/15/2015	Two Creek	305	10/17/2016	Two Creek	366.0.5	1.01	61	60
3D6 0017F7A407	10/15/2015	Two Creek	302	10/17/2016	Two Creek	348 0 5	1.01	46	45
JJ0.001/1//11/0/	10/13/2013	Cottonwood	562	10/17/2010	Cottonwood	540, 0.5	1.01	-10	75
3D6 001808 4 860	5/25/2016	Creek	178 0 1	6/23/2016	Creak	213 0 1	0.08	36	118
3D6.001000A003	10/15/2015	Two Crook	170, 0.1	10/0/2010	Two Crook	213, 0.1	2.00	10	2
2D6 00101F2D33	10/13/2013	Two Creek	455	10/7/2010	Two Creek	405, 1.0	2.77	10	5 50
3D0.00182C03DF	10/22/2013	I WO CIEEK	237	10/10/2018	I WO CIEEK	411, 0.7	2.97	155	32
20 (0010200255	2/24/2016	BIACKTAIL	269.05	0/12/2016	BIACKTAIL	296.9.6	0.47	10	20
3D6.00182C03E/	3/24/2016	Creek	368, 0.5	9/13/2016	Creek	386, 0.6	0.47	18	58
3D6.00182C0406	10/15/2015	Two Creek	445	10/17/2016	Two Creek	460, 0.8	1.01	15	15

2357 Table 24 – continued

PIT Date taged Subwatershed weight (mm, kg) Date weight (mm, kg) Subwatershed (mm, kg) length (mm, kg) (mm, kg) (mm, kg) (Growth (mm) (mm) (Growth (mm) (mm) <t< th=""><th></th><th></th><th></th><th>Tagging</th><th></th><th></th><th>Recapture</th><th>Time to</th><th></th><th>Crowth</th></t<>				Tagging			Recapture	Time to		Crowth
read weight (mm, kg) recaptured (mm, kg) weight (mm) year) recaptured (mm) year) weight (mm) year) recaptured (mm) year) 3D6.00182C0421 [0152015] Two Creek 254 928/2018 Two Creek 320, 0.3 1.01 66 66 5D6.00182C045A [0152015] Two Creek 254 928/2018 Two Creek 435, 0.4 1.01 1.09 108 5D6.00182C049A [0152015] Two Creek 433 10017/2016 Two Creek 447, 0.7 1.01 74 73 5D6.00182C049A [0152015] Two Creek 211 10017/2016 Two Creek 452, 1.0 1.01 1.14 113 5D6.00182C04AB [0152015] Two Creek 261 1007/2016 Two Creek 452, 1.0 1.00 83 17 5D6.00182C0540 5/25/2016 Creek 452 1.01 1.43 43 26 5D6.00182C0540 5/25/2016 Creek 429, 0.8 6/23/2016 Creek 452, 1.0 0.08 5	ріт	Date	Subwatershed	length,	Date	Subwatershed	length,	racentura	Growth	roto
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	PII	tagged	tagged	weight	recaptured	recaptured	weight	(voors)	(mm)	(mm/voor)
3D6.00182C044 10152015 Two Creek 254 10172016 Two Creek 320, 0.3 1.01 66 66 5D6.00182C044A 10152015 Two Creek 254 9282018 Two Creek 345, 0.4 1.01 109 108 5D6.00182C0490 10152015 Two Creek 433 10172016 Two Creek 447, 0.7 1.01 74 73 5D6.00182C0490 10152015 Two Creek 211 10172016 Two Creek 325, 0.4 1.01 1.14 113 5D6.00182C0490 10152015 Two Creek 239 10172016 Two Creek 452, 1.1 1.98 33 1.7 5D6.00182C044B 10152015 Two Creek 63 10172016 Two Creek 452, 1.1 1.08 33 1.7 5D6.00182C0540 5242016 Creek 63 10172016 Two Creek 452, 1.1 1.08 33 1.7 5D6.00182C0540 5242016 Creek 452, 1.0 0.08 Cottonwood 224 <td></td> <td></td> <td></td> <td>(mm, kg)</td> <td>_</td> <td>_</td> <td>(mm, kg)</td> <td>(years)</td> <td></td> <td>(IIIII/year)</td>				(mm, kg)	_	_	(mm, kg)	(years)		(IIIII/year)
3D6.00182C0444 10/15/2015 Two Creek 2354 9.28.2018 Two Creek 483, 1.2 2.96 229 77 3D6.00182C0492 10/15/2015 Two Creek 236 10/17/2016 Two Creek 478, 1.3 1.01 38 38 3D6.00182C0492 10/15/2015 Two Creek 343 10/17/2016 Two Creek 478, 1.3 1.01 38 38 3D6.00182C0490 10/15/2015 Two Creek 251 10/24/2016 Two Creek 419, 0.9 1.01 20 20 3D6.00182C04A6 10/15/2015 Two Creek 429, 0.8 623/2016 Creek 452, 1.0 0.08 2.3 2.88 Cottonwood Cottonwood Cottonwood Cottonwood Cottonwood 70 -4 3D6.00182C054F 5/24/2016 Creek 429, 0.4 77/2016 Creek 429, 0.2 71 -3 -4 Cottonwood Cottonwood Cottonwood Cottonwood 1.01 1.07 1.07 1.01 1.07	3D6.00182C0421	10/15/2015	Two Creek	254	10/17/2016	Two Creek	320, 0.3	1.01	66	66
3D6.00182C045A 101/52015 Two Creek 2326 101/12016 Two Creek 245, 0.4 1.01 1.09 108 3D6.00182C0496 101/52015 Two Creek 433 101/12016 Two Creek 447, 0.7 1.01 7.4 7.3 3D6.00182C049A 101/52015 Two Creek 211 101/12016 Two Creek 439, 0.4 1.01 1.14 1.13 3D6.00182C04AB 101/52015 Two Creek 321 101/12016 Two Creek 452, 1.1 1.98 3.3 1.7 3D6.00182C04AB 101/52015 Two Creek 429, 0.8 6/23/2016 Creek 452, 1.0 0.08 2.3 2.88 Cottonwood Cottonwood Creek 429, 0.8 6/23/2016 Creek 452, 1.0 0.08 2.3 2.88 3D6.00182C054 5/25/2016 Creek 429, 0.8 6/23/2016 Creek 452, 1.0 0.08 5 64 3D6.00182C054 5/25/2016 Creek 457, 0.9 6/23/2016 Creek	3D6.00182C0444	10/15/2015	Two Creek	254	9/28/2018	Two Creek	483, 1.2	2.96	229	77
3D5.00182C0492 10/15/2015 Two Creek 433 10/18/2016 Two Creek 443 10/17/2016 Two Creek 447, 1.7 1.01 38 38 3D5.00182C0498 10/15/2015 Two Creek 343 10/17/2016 Two Creek 345, 0.5 1.03 94 91 3D5.00182C04A6 10/15/2015 Two Creek 211 10/17/2016 Two Creek 419, 0.9 1.01 20 20 3D5.00182C04A6 10/15/2015 Two Creek 303 10/17/2016 Two Creek 452, 1.1 1.98 33 17 3D5.00182C04A8 10/15/2015 Two Creek 429, 0.8 623/2016 Creek 452, 1.0 0.08 23 288 Cottonwood 100/12/016 Two Creek 429, 0.1 7/7/2016 Creek 420, 0.1 Creek 200, 0.2 0.71 -3 -4 Cottonwood 10/15/2015 Two Creek 424, 0.1 7/7/2016 Creetwowd 421, 0.1 0.08 5 44 306.00182C054E<	3D6.00182C045A	10/15/2015	Two Creek	236	10/17/2016	Two Creek	345, 0.4	1.01	109	108
3D6.00182C0496 IO152015 Two Creek 2343 IO172016 Two Creek 417, 0.7 I.01 74 73 3D6.00182C049A IO152015 Two Creek 211 IO1772016 Two Creek 345, 0.5 I.03 94 91 3D6.00182C04A6 IO152015 Two Creek 211 IO1772016 Two Creek 419, 0.9 I.01 20 20 3D6.00182C04A6 IO152015 Two Creek 363 IO172016 Two Creek 452, I.1 I.98 33 17 3D6.00182C0529 5252016 Creek 429, 0.8 6232016 Creek 452, I.0 0.08 23 288 3D6.00182C054P 5252016 Creek 249, 0.1 7/72016 Creek 452, I.0 0.08 5 64 3D6.00182C054E 5252016 Creek 247, 0.9 6232016 Creek 451, 0.0 0.8 15 192 3D6.00182C056E 5252016 Creek 257 3/24/2016 Creek 439, 1.0	3D6.00182C0492	10/15/2015	Two Creek	439	10/18/2016	Two Creek	478, 1.3	1.01	38	38
3D6.00182C0498 10/15/2015 Two Creek 211 10/17/2016 Two Creek 325, 0.4 1.01 114 113 3D6.00182C04A6 10/15/2015 Two Creek 211 10/17/2016 Two Creek 419, 0.9 1.01 1.01 1.01 20 20 3D6.00182C04A6 10/15/2015 Two Creek 363 10/17/2016 Two Creek 496, 0.8 1.01 43 43 3D6.00182C0529 5/25/2016 Creek 429, 0.8 6/23/2016 Creek 452, 1.0 0.08 23 288 Cottonwood Creek 249, 0.1 7/7/2016 Creek 269, 0.2 0.71 -3 -4 3D6.00182C054P 5/25/2016 Creek 457, 0.9 6/23/2016 Creek 401 1.67 135 80 3D6.00182C054F 5/25/2016 Creek 424, 0.8 6/23/2016 Creek 430, 0.08 15 192 3D6.00182C054F 5/25/2016 Creek 424, 0.8 6/23/2016 Creek 430<	3D6.00182C0496	10/15/2015	Two Creek	343	10/17/2016	Two Creek	417, 0.7	1.01	74	73
3D6.00182C04A6 10/15/2015 Two Creek 3211 10/17/2016 Two Creek 419, 0.9 1.01 114 113 3D6.00182C04A6 10/15/2015 Two Creek 339 10/17/2016 Two Creek 452, 1.1 1.98 33 17 3D6.00182C054B 10/15/2015 Two Creek 363 10/17/2016 Two Creek 452, 1.0 0.08 2.3 288 3D6.00182C054D 5/24/2016 Creek 429, 0.1 7/7/2016 Creek 452, 1.0 0.08 2.3 288 3D6.00182C054D 5/24/2016 Creek 249, 0.1 7/7/2016 Creek 452, 1.0 0.08 5 44 3D6.00182C054F 5/24/2016 Creek 249, 0.1 7/7/2016 Creek 420, 0.1 7.7 Creek 260, 0.2 0.1 .3 1.4 3D6.00182C057E 5/25/2016 Creek 424, 0.8 6/32/2016 Creek 430, 1.0 0.08 15 192 3D6.00182C057E 10/15/2014 Wo Creek	3D6.00182C0498	10/15/2015	Two Creek	251	10/24/2016	Two Creek	345, 0.5	1.03	94	91
3D6.00182C04A6 10/15/2015 Two Creek 399 10/17/2016 Two Creek 419, 0.9 1.01 20 20 3D6.00182C04AB 10/15/2015 Two Creek 363 10/17/2016 Two Creek 445, 1.1 1.98 33 17 3D6.00182C0529 5/25/2016 Creek 429, 0.8 6/23/2016 Creek 452, 1.0 0.08 23 288 Catomwood Catomwood Catomwood Catomwood 10 269, 0.2 0.12 23 190 3D6.00182C0540 5/24/2016 Creek 457, 0.9 6/23/2016 Creek 269, 0.2 0.71 -3 -4 3D6.00182C054F 5/25/2016 Creek 457, 0.9 6/23/2016 Creek 439, 1.0 0.08 15 192 3D6.00182C055C 10/15/2015 Two Creek 457, 0.9 6/23/2016 Creek 439, 1.0 0.08 15 192 3D6.00182C055C 10/15/2014 Moose Creek 427, 0.8 C32/2016 Creek 439, 1.0	3D6.00182C049A	10/15/2015	Two Creek	211	10/17/2016	Two Creek	325, 0.4	1.01	114	113
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	3D6.00182C04A6	10/15/2015	Two Creek	399	10/17/2016	Two Creek	419, 0.9	1.01	20	20
3D6.00182C04AB 10/15/2015 Two Creek Contonwood 406, 0.8 1.01 43 43 3D6.00182C0529 5/25/2016 Creek 429, 0.8 6/23/2016 Creek 452, 1.0 0.08 23 288 3D6.00182C0540 5/24/2016 Creek 429, 0.1 7/7/2016 Creek 480, 1.1 0.75 28 37 3D6.00182C0540 5/24/2016 Creek 249, 0.1 7/7/2016 Creek 420, 0.2 0.71 -3 -4 SD6.00182C054F 5/25/2016 Creek 437, 0.9 6/23/2016 Creek 420, 0.0 0.08 15 192 3D6.00182C054F 5/25/2016 Creek 240, 0.6 6/23/2017 Two Creek 401 1.67 135 80 3D6.00182C054C 10/15/2015 Two Creek 267 6/17/2017 Two Creek 401 1.67 135 80 384.3515DE9D3T 10/14/2014 Creek 257 3/24/2016 Creek 305, 0.3 2.50 46 18 <td></td> <td></td> <td></td> <td></td> <td>10/9/2018</td> <td>Two Creek</td> <td>452, 1.1</td> <td>1.98</td> <td>33</td> <td>17</td>					10/9/2018	Two Creek	452, 1.1	1.98	33	17
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	3D6.00182C04AB	10/15/2015	Two Creek	363	10/17/2016	Two Creek	406, 0.8	1.01	43	43
3D6.00182C0529 5/25/2016 Creek 429, 0.8 6/23/2016 Creek 480, 1.1 0.75 28 37 3D6.00182C0540 5/24/2016 Creek 249, 0.1 7/7/2016 Creek 480, 1.1 0.75 28 37 3D6.00182C0540 5/24/2016 Creek 249, 0.1 7/7/2016 Creek 269, 0.2 0.11 -3 -4 Cottonwood Cottonwood - Cottonwood -			Cottonwood			Cottonwood				
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	3D6.00182C0529	5/25/2016	Creek	429, 0.8	6/23/2016	Creek	452, 1.0	0.08	23	288
$\begin{array}{c c c c c c c c c c c c c c c c c c c $						Cottonwood				
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $					3/23/2017	Creek	480, 1.1	0.75	28	37
3D6.00182C0540 5/24/2016 Creek 249, 0.1 7/7/2016 Creek 272 0.12 23 190 3D6.00182C054F 5/25/2016 Creek 457, 0.9 6/23/2017 Creek 269, 0.2 0.71 -3 -4 3D6.00182C054F 5/25/2016 Creek 457, 0.9 6/23/2016 Creek 462, 1.0 0.08 5 64 3D6.00182C05CA 10/15/2015 Two Creek 267 6/17/2017 Two Creek 401 1.67 135 80 384.3515DE9BC5 10/14/2014 Creek 257 3/24/2016 Creek 312, 0.3 1.44 46 39 384.3515DE9D37 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 8 3 384.3515DE9D37 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 18 384.3515DE9D37 10/15/2015 Two Creek 358 10/18/2016 Two Creek 380, 0.4			Upper Sheep			Upper Sheep				
Cottonwood Si/23/2017 Coreek Creek 269, 0.2 0.71 -3 -4 3D6.00182C054F 5/25/2016 Creek 457, 0.9 6/23/2016 Creek 462, 1.0 0.08 5 64 3D6.00182C056E 5/25/2016 Creek 424, 0.8 6/23/2016 Creek 439, 1.0 0.08 15 192 3D6.00182C056E 5/25/2016 Creek 267 6/17/2017 Two Creek 401 1.67 135 80 3D6.00182C057A 10/15/2015 Two Creek 257 3/24/2016 Creek 312, 0.3 1.44 46 39 384.3515DE9D3E 10/15/2014 Moose Creek 297 4/14/2017 Creek 305, 0.3 2.50 8 3 384.3515DE9D3E 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 188 384.3515DE9D3E 10/15/2015 Two Creek 333 10/17/2016 Two Creek 336, 0.4 1.01 13 3	3D6.00182C0540	5/24/2016	Creek	249, 0.1	7/7/2016	Creek	272	0.12	23	190
$\begin{array}{c c c c c c c c c c c c c c c c c c c $						Cottonwood				
$\begin{array}{c c c c c c c c c c c c c c c c c c c $					3/23/2017	Creek	269, 0.2	0.71	-3	-4
3D6.00182C054F 5/25/2016 Creek Cottonwood 457, 0.9 6/23/2016 Cottonwood Creek Cottonwood 462, 1.0 0.08 5 64 3D6.00182C056E 5/25/2016 Creek 424, 0.8 6/23/2016 Creek 439, 1.0 0.08 15 192 3D6.00182C05CA 10/15/2015 Two Creek 267 6/17/2017 Two Creek 401 1.67 135 80 Mountain Whitefish Cottonwood Blacktail 1 1.67 135 80 384.3515DE9D3E 10/15/2014 Moose Creek 297 4/14/2017 Creek 305, 0.3 2.50 8 3 384.3515DE9D57 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2015 Two Creek 315 10/17/2016 Two Creek 366, 0.5 2.19 33 15 306.0017F7A2CD 10/15/2015 Two Creek 358 10/18/2016 Two Creek 338, 0.4 1.03			Cottonwood			Cottonwood				
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	3D6.00182C054F	5/25/2016	Creek	457, 0.9	6/23/2016	Creek	462, 1.0	0.08	5	64
3D6.00182C05CA 5/25/2016 Creek 424, 0.8 6/23/2016 Creek 439, 1.0 0.08 1.5 192 3D6.00182C05CA 10/15/2015 Two Creek 267 6/17/2017 Two Creek 401 1.67 135 80 Cottonwood Blacktail Statistic Creek 312, 0.3 1.44 46 39 Statistic Creek 312, 0.3 1.44 46 39 Statistic Creek 312, 0.3 1.44 46 39 Statistic Creek 312, 0.17 Creek 305, 0.3 2.50 8 3 Statistic Creek 312, 0.177 Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2014 Moose Creek 358 10/17/2016 Two Creek 328, 0.4 1.01 13 13 306.0017F7A2CD 10/15/2015 Two Creek 358 10/24/2016 Two Creek 338, 0.4 1.01 15 15			Cottonwood			Cottonwood				
3D6.00182C05CA 10/15/2015 Two Creek 267 6/17/2017 Two Creek 401 1.67 135 80 Mountatin White/ish Blacktail 384.3515DE9D55 10/14/2014 Creek 257 3/24/2016 Creek 312, 0.3 1.44 46 39 Statistic Creek 257 3/24/2016 Creek 305, 0.3 2.50 8 3 Blacktail 384.3515DE9D57 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2015 Two Creek 315 10/18/2016 Two Creek 328, 0.4 1.01 13 13 3D6.0017F7A2E6 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.01 15 15 3D6.0017F7A2F6 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.01 15 15 3D6.00187FA3P8 9/24/2015 Creek 163 3/23/2017	3D6.00182C056E	5/25/2016	Creek	424, 0.8	6/23/2016	Creek	439, 1.0	0.08	15	192
Mountain White/ish 384.3515DE9BC5 10/14/2014 Creek 257 3/24/2016 Creek 312, 0.3 1.44 46 39 384.3515DE9D3E 10/14/2014 Moose Creek 257 3/24/2016 Creek 305, 0.3 2.50 8 3 384.3515DE9D57 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2015 Two Creek 333 10/17/2016 Two Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2015 Two Creek 333 10/17/2016 Two Creek 328, 0.4 1.01 13 13 306.0017F7A2E0 10/15/2015 Two Creek 337 10/14/2016 Two Creek 338, 0.4 1.01 15 15 306.0017F7A2F6 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.01 15 15 306.00187F7A390 10/15/2015 Two Creek	3D6.00182C05CA	10/15/2015	Two Creek	267	6/17/2017	Two Creek	401	1.67	135	80
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384.3515DE9BC5 10/14/2014 Creek 257 3/24/2016 Creek 312, 0.3 1.44 46 39 384.3515DE9D3E 10/15/2014 Moose Creek 297 4/14/2017 Creek 305, 0.3 2.50 8 3 384.3515DE9D57 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2015 Two Creek 313 10/17/2016 Two Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2015 Two Creek 315 10/18/2016 Two Creek 328, 0.4 1.01 13 13 3D6.0017F7A2B0 10/15/2015 Two Creek 358 10/24/2016 Two Creek 338, 0.4 1.01 15 15 3D6.0017F7A300 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.01 15 15 Blacktail Blacktail Blacktail Blacktail 1.01 0.83 48 58 3D6.001807A418 9/24/2015 Creek			Cottonwood			Blacktail				
384.3515DE9D3E 10/15/2014 Moose Creek 297 4/14/2017 Creek Blacktail 305, 0.3 2.50 8 3 384.3515DE9D57 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2015 Two Creek 333 10/17/2016 Two Creek 366, 0.5 2.19 33 15 306.0017F7A2E0 10/15/2015 Two Creek 315 10/18/2016 Two Creek 328, 0.4 1.01 13 13 3D6.0017F7A2E0 10/15/2015 Two Creek 335 10/24/2016 Two Creek 338, 0.4 1.03 23 22 3D6.0017F7A2F6 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.03 23 22 3D6.0017F7A2F0 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.01 13 13 3D6.001807A418 9/24/2015 Creek 163 3/23/2017 C	384.3515DE9BC5	10/14/2014	Creek	257	3/24/2016	Creek	312, 0.3	1.44	46	39
384.3515DE9D3E 10/15/2014 Moose Creek 297 4/14/2017 Creek 305, 0.3 2.50 8 3 384.3515DE9D57 10/15/2014 Moose Creek 259 4/13/2017 Creek 305, 0.3 2.50 46 18 384.3515DE9D57 10/15/2014 Two Creek 333 10/17/2016 Two Creek 366, 0.5 2.19 33 15 3D6.0017F7A2E0 10/15/2015 Two Creek 315 10/18/2016 Two Creek 388, 0.4 1.01 13 13 3D6.0017F7A2E0 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.03 23 22 3D6.0017F7A3P0 10/15/2015 Two Creek 323 10/18/2016 Two Creek 338, 0.4 1.01 15 15 Blacktail Diacktail Diacktail <t< td=""><td></td><td></td><td></td><td></td><td></td><td>Blacktail</td><td></td><td></td><td></td><td></td></t<>						Blacktail				
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	384.3515DE9D3E	10/15/2014	Moose Creek	297	4/14/2017	Creek	305, 0.3	2.50	8	3
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$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	384.3515DE9D57	10/15/2014	Moose Creek	259	4/13/2017	Creek	305, 0.3	2.50	46	18
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	384.358D117C6F	8/9/2014	Two Creek	333	10/17/2016	Two Creek	366, 0.5	2.19	33	15
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	3D6.0017F7A2B0	10/15/2015	Two Creek	315	10/18/2016	Two Creek	328, 0.4	1.01	13	13
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$\begin{array}{c c c c c c c c c c c c c c c c c c c $	3D6.0017F7A390	10/15/2015	Two Creek	323	10/18/2016	Two Creek	338, 0.4	1.01	15	15
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Cottonwood Cottonwood 3D6.00182C052C 5/25/2016 Creek 396, 0.7 3/23/2017 Creek 406, 0.7 0.83 10 12 3D6.00182C053E 5/24/2016 Creek 284, 0.2 7/7/2016 Creek 292 0.12 8 63 3D6.00182C053E 5/24/2016 Creek 284, 0.2 7/7/2016 Creek 290, 0.2 0.77 -3 -3 Upper Sheep Upper Sheep Upper Sheep Upper Sheep Blacktail 3D6.00182C0575 5/24/2016 Creek 302, 0.2 4/13/2017 Creek 306, 0.2 0.89 4 4 3D6.00182C0573 10/15/2015 Two Creek 343 10/17/2016 Two Creek 348 1.01 15 5 3D6.00182C0594 10/15/2015 Two Creek 335 10/17/2016 Two Creek 348 1.01 13 13 3D6.00182C0594 10/15/2015 Two Creek 343 10/18/2016 Two Creek 361 0.4	3D6.00182C040B	10/15/2015	Two Creek	310	10/18/2016	Two Creek	330, 0.3	1.01	20	20
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$\frac{10}{10} \frac{10}{10} 10$	3D6.00182C059D	10/15/2015	Two Creek	343	10/18/2016	Two Creek	361, 0.4	1.01	18	18
3D6.00182C059F 10/15/2015 Two Creek 414 10/17/2016 Two Creek 422, 0.7 1.01 8 8	3D6.00182C059F	10/15/2015	Two Creek	414	10/17/2016	Two Creek	422, 0.7	1.01	8	8

2359 Table 24 – continued

PIT	Date tagged	Subwatershed tagged	Tagging length, weight (mm, kg)	Date recaptured	Subwatershed recaptured	Recapture length, weight (mm, kg)	Time to recapture (years)	Growth (mm)	Growth rate (mm/year)
3D6.00182C05C0	10/15/2015	Two Creek	315	10/18/2016	Two Creek	325, 0.3	1.01	10	10
3D6.00182C05C7	10/15/2015	Two Creek	384	10/17/2016	Two Creek	396, 0.6	1.01	13	13
				Brook Trou	t				
		Cottonwood			Cottonwood				
3D6.00182C056C	5/25/2016	Creek	239, 0.1	6/23/2016	Creek	264, 0.2	0.08	25	320
				Burbot					
		Blacktail			Blacktail				
384.3515DC4184	9/18/2014	Creek	483	9/13/2016	Creek	536, 1.0	1.99	53	27
3D6.00182C04A8	10/15/2015	Two Creek	615	10/17/2016	Two Creek	660, 2.4	1.01	46	45
		Blacktail			Blacktail				
3D6.00182C055C	3/24/2016	Creek	584, 1.2	9/13/2016	Creek	584, 1.2	0.47	0	0
				White Sucke	er				
3D6.00182C04AA	10/15/2015	Two Creek	414	10/18/2016	Two Creek	419, 1.0	1.01	5	5
2260									

FIGURES



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Figure 4.1. The upper Missouri, Sun, and Smith rivers and their major tributaries. Yellow dots
represent USGS gaging stations used in the study. Black diagonals represent dams or diversions.
Green diamonds represent fixed PIT antenna arrays. Shaded buffers represent areas where fish

- 2369 movement was monitored by fixed PIT antenna arrays, portable PIT antennas, and physical
- recapture events.



Figure 4.2. Operation timelines of stationary PIT arrays in the Smith, Sun, and upper Missouri

- 2373 River subbasins from 2011 to 2020.
- 2374



Figure 4.3. Length-frequency distributions of rainbow trout, brown trout, and mountain whitefish

- captured and tagged in the upper Missouri River and its tributaries from 2014 to 2016. Gray bars
 - 2378 represent fish tagged in tributaries whereas black bars represent fish tagged in the mainstem
 - 2379 river.



Figure 4.4. Distributions of time intervals between date tagged and date of last detection of

rainbow trout, brown trout, and mountain whitefish tagged and redetected in the upper MissouriRiver, Sun River, and Smith River from 2010 to 2020.



2384 2385 Figure 4.5. Length at tagging and time interval between date tagged and date of last detection of

2386 rainbow trout, brown trout, and mountain whitefish redetected in the upper Missouri River, Sun 2387 River, and Smith River from 2010 to 2020.



2389 Figure 4.6. Yearly growth rates of rainbow trout, brown trout, and mountain whitefish

2390 recaptured, measured, and weighed in the upper Missouri River, Sun River, and Smith River

from 2014 to 2020.



2393 Figure 4.7. Growth curves of rainbow trout, brown trout, and mountain whitefish recaptured,

2394 measured, and weighed in the upper Missouri River, Sun River, and Smith River from 2014 to

2395 2020 from initial tagging date to date of final recapture.



Figure 4.8. Length-frequency distributions of rainbow trout, brown trout, and mountain whitefish captured and tagged in the Sun River in 2015.



Figure 4.9. Length-frequency distributions of rainbow trout, brown trout, and mountain whitefish captured and tagged in the Smith River and its tributaries from 2010 to 2017. Gray bars represent fish tagged in tributaries whereas black bars represent fish tagged in the mainstem river.



- 2405 Figure 4.10. Relative weights of rainbow trout captured, measured, and weighed by tagging
- 2406 location (watershed) from 2010 to 2018 in the Smith River subbasin. Proportion is represented
- by the gray gradient, with darker shades indicating a higher percentage. Light blue areas
- 2408 represent watersheds that were not part of the analysis.



- Figure 4.11. Relative weights of brown trout captured, measured, and weighed by tagging
- 2411 location (watershed) from 2011 to 2018 in the Smith River subbasin. Proportion is represented
- by the gray gradient, with darker shades indicating a higher percentage. Light blue areas
- 2413 represent watersheds that were not part of the analysis.



- 2414
- Figure 4.12. Relative weights of mountain whitefish captured, measured, and weighed by tagging
- location (watershed) from 2010 to 2017 in the Smith River subbasin. Proportion is represented
- 2417 by the gray gradient, with darker shades indicating a higher percentage. Light blue areas
- 2418 represent watersheds that were not part of the analysis.
- 2419

2420	CHAPTER FIVE
2421	
2422	CONCLUSIONS
2423	
2424	Life history patterns of salmonid populations in the upper Missouri River basin are
2425	diverse and vary among subbasins, watersheds, species, years, and seasons. This study provides
2426	further insights into such patterns, but a comprehensive understanding requires comparisons to
2427	complementary studies implementing an assortment of methodologies. Outmigration is
2428	influenced by a variety of abiotic factors that themselves vary considerably as components of a
2429	dynamic river system. Similar to previous studies on Missouri River tributaries, a bimodal
2430	outmigration pattern was observed in most streams and the outmigration often appeared related
2431	to changes in discharge. Outmigration occurred the earliest in the smallest streams, which may
2432	be an adaptive response to reduced habitat availability with a decrease in discharge in smaller
2433	streams. Although straying rates are lower than expected, spawning patterns are potentially more
2434	diverse than previously thought and suggest multiple life history patterns. This is further
2435	supported by the low incidence of outmigration movements. Minimum homing rates were
2436	generally greater than straying rates, but many fish could not be categorized or were unaccounted
2437	for and could have been tributary residents, mortalities, or undetected. Mainstem spawning
2438	patterns are probably more complex than those of tributary spawners, but sample sizes and the
2439	ability to monitor fish in the mainstem limits the ability to make conclusions. Growth rates in the
2440	upper Missouri River subbasin remain high, but longevity in the Smith River is highest relative
2441	to the upper Missouri River and Sun River. Inter-subbasin connectivity among fish populations
2442	does exist and likely contributes to an already diverse genetic composition, though the full

2443 extents of either are still unknown. The complexity in life history patterns of salmonids in the

2444 upper Missouri River basin probably contributes to the persistence and productivity of the

2445 fishery in the presence of highly variable environmental disturbances, including whirling disease.

2446 Maintaining and promoting this complexity requires management that facilitates connectivity at

both spatial and temporal scales. Temporal variation in life histories suggests future studies

2448 would benefit from simultaneous application of multiple methodologies.

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APPENDIX

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Table A1. Summary statistics for top-ranked models for number of outmigrants of rainbow and Brown trout in Little Prickly Pear Creek and Dearborn River. Numbers in parentheses next to variables denote the categorical level within each variable. 'Num. mods' indicates how many of the top models and 'Importance' indicates the proportion of models each variable was included in. 'SE' is standard error and 'Adj. SE' is adjusted standard error.

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Site	Species	Variable	Num. mod.	Importance	β	SE	Adj. SE	Z	р
Little Prickly Pear	Rainbow Trout	Intercept	2	1.0	-1.10	0.26	0.26	4.15	< 0.001
		Photoperiod(2)	2	1.0	0.51	0.33	0.33	1.53	0.126
		Photoperiod(3)	2	1.0	-1.79	0.59	0.59	3.00	0.003
		Lunar phase(2)	1	0.5	0.03	0.18	0.18	0.18	0.861
		Lunar phase(3)	1	0.5	0.01	0.14	0.14	0.04	0.966
		Lunar phase(4)	1	0.5	0.08	0.27	0.27	0.30	0.763
	Brown Trout	Intercept	4	1.0	-2.70	0.39	0.39	6.847	< 0.001
		Photoperiod(2)	2	0.5	-0.02	0.38	0.38	0.063	0.949
		Photoperiod(3)	2	0.5	-0.95	1.16	1.16	0.820	0.412
		Lunar phase(2)	2	0.5	0.10	0.36	0.36	0.273	0.785
		Lunar phase(3)	2	0.5	0.01	0.28	0.28	0.048	0.961
		Lunar phase(4)	2	0.5	0.15	0.44	0.44	0.344	0.731
Dearborn	Rainbow Trout	Intercept	5	1.0	-2.16	0.45	0.45	4.749	< 0.001
		Photoperiod(2)	1	0.2	0.07	0.23	0.23	0.313	0.754
		Photoperiod(3)	1	0.2	-0.08	0.28	0.28	0.274	0.784
		Temperature(2)	1	0.2	0.04	0.27	0.27	0.138	0.890
		Temperature(3)	1	0.2	-0.02	0.28	0.28	0.075	0.940
		Temperature(4)	1	0.2	0.10	0.33	0.33	0.312	0.755
		Temperature(5)	1	0.2	0.15	0.41	0.41	0.376	0.707
		Discharge(2)	1	0.2	-0.12	0.38	0.38	0.316	0.752
		Discharge(3)	1	0.2	-0.08	0.30	0.30	0.260	0.795
		Discharge(4)	1	0.2	-0.11	0.38	0.38	0.290	0.772
		Discharge(5)	1	0.2	-0.16	0.54	0.54	0.301	0.763
		Lunar phase(2)	1	0.2	-0.06	0.26	0.26	0.210	0.834
		Lunar phase(3)	1	0.2	0.02	0.14	0.14	0.170	0.865
		Lunar phase(4)	1	0.2	-0.02	0.18	0.18	0.108	0.914

2669

2671 Table A2. Summary statistics testing for dispersion for each site × species combination. Bold *P*2672 values indicate when a negative binomial was used instead of a poisson distribution. 'Dispersion'

2673 is the estimate of dispersion for each global model.

	Site	Species	Dispersion	z	Р
	Little Prickly Pear Creek	Rainbow Trout	1.75	3.41	< 0.001
		Brown Trout	0.94	-2.16	0.985
	Dearborn River	Rainbow Trout	1.13	1.12	0.131
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2692 Figure A1. Common patterns of outmigration observed in rainbow trout tagged in Lyons and 2693 Wolf creeks in 2014. Black lines represent the most frequent outmigration pattern characterized 2694 by a relatively fast rate of migration. Green lines represent individuals that exited Wolf or Lyons 2695 Creek first, then remained in Little Prickly Pear Creek for some time before migrating to the 2696 Missouri River. Red lines represent individuals that were repeatedly detected on the Little 2697 Prickly Pear Creek antenna array at the confluence with the Missouri River before finally 2698 entering the main stem river. Blue lines represent discharge of Little Prickly Pear Creek at the 2699 USGS gaging station.



Figure A2. Comparisons of measured mean daily water temperatures and estimated mean daily
water temperatures for Wolf and Lyons creeks and the Dearborn River from March 1 to
November 30, 2015 and for Little Prickly Pear Creek from March 1 to November 30, 2003. Solid
blue lines represent measured mean daily water temperatures whereas solid green lines represent
estimated mean daily water temperatures.





Figure A3. Detections of PIT-tagged rainbow trout tagged in Upper Missouri River tributaries in2014 on all upper Missouri River PIT antennas. Individuals that were classified as outmigrants in

- 2712 2015 were excluded from the 2015 graph.
- 2713



Figure A4. Detections of mature rainbow trout (age 3+, >300 mm at tagging) on upper Missouri
River tributary PIT antennas from 2016 to 2018.