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Assessing the Movement Ecology of a Native Fish Assemblage in the Dolores River Basin

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ASSESSING THE MOVEMENT ECOLOGY OF A NATIVE FISH ASSEMBLAGE IN THE DOLORES RIVER BASIN

by

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CHAPTER 1

EVALUATION OF THE LARGE-SCALE MOVEMENT PATTERNS OF FLANNELMOUTH SUCKER, BLUEHEAD SUCKER AND ROUNDTAIL CHUB

Introduction

Movement is a distinguishable characteristic amidst nearly all forms of life, as most organisms will exhibit movement at some scale throughout their life cycle (Holyoak et al. 2008; Nathan et al. 2008; Booth et al. 2014). Organisms often move in response to information and to realize “goals” (Holyoak et al. 2008). Realizing these “goals” is motivated by a wide range of needs including locating resources (food and water), seeking mates, accessing breeding sites, avoiding adverse environmental conditions, locating seasonally important habitats and exploring new habitats (Mueller and Fagan 2008; Comte and Olden 2018; Rozman et al. 2021). The importance of movement is far-reaching and substantial because of the immeasurable role it plays for individuals, populations, communities and ecosystems (Skalski and Gilliam 2000; Allen and Singh 2016; Comte and Olden 2018). Essential large-scale processes that movement enables include maintaining population dynamics, expediting genetic mixing, connecting landscapes through facilitating nutrient exchange and ultimately influencing the evolution of organisms and ecosystems (Nathan et al. 2008; Rolls et al. 2013; Bauer et al. 2016; Spurgeon et al. 2018).

Similar to other highly mobile taxa, movement is fundamental to the persistence of many fish (Skalski and Gilliam 2000; Spurgeon et al. 2018; Lopes et al. 2019). Movement of fishes throughout riverine landscapes is necessary to fulfill many of the fundamental processes of life, including reproduction, foraging, growth, predator avoidance, and completion of life history requirements (Crook et al. 2015; Spurgeon et al. 2018). Individual fitness, population persistence and community structure are all influenced by fish movement (Skalski and Gilliam 2000). The significance of movement on multiple scales for the persistence of fish is well recognized, as is the importance of studying movement for improved fisheries management (Booth et al. 2014; Hooley-Underwood et al. 2019; Lopes et al. 2019; Cathcart et al. 2019).

Assessing movement patterns provides a wide range of information that can help guide management actions and direct conservation planning. Generally, management actions are less effective when they fail to account for the spatial ecology of target populations (Nathan et al. 2008). Hence, it is recommended that movement ecology should be incorporated into conservation planning (Allen and Singh 2016). One motivation for assessing movement patterns is an increased understanding of the spatial ecology of populations (Cooke et al. 2016). Such knowledge can illuminate key habitats, identify migration corridors or lack thereof (i.e. barriers), assess connectivity, aid development of effective assessment techniques and evaluate the effects of human actions (i.e. land-use, land management) on spatiotemporal distributions and abundances of populations (Mueller and Fagan 2008; Rolls et al. 2013; Booth et al. 2014; Lopes et al. 2019).

Native fishes in the southwestern United States have declined considerably within the last century, in both abundance and range (Minckley and Deacon 1968; Rinne and Miller 2006), making detailed biological assessments of movement patterns and describing spatial ecology of these fishes increasingly necessary to inform conservation planning. A growing number of studies have documented and described the spatial ecology and movement patterns of imperiled fish species native to the Colorado River basin, utilizing a variety of monitoring techniques.

(Modde et al. 2005; Sweet and Hubert 2010; Pennock et al. 2020). Flannelmouth Sucker (*Catostomus latipinnis),* Bluehead Sucker (*Catostomus discobolus*) and Roundtail Chub (*Gila robusta*) (hereafter, three-species) are one such assemblage of diminishing native Colorado River basin fishes that have recently been the subjects of several movement studies within some of the waters that they occupy (Compton et al. 2008; Fraser et al. 2017; Cathcart et al. 2019; Hooley-Underwood et al. 2019). Within the upper Colorado River basin, a status review of three-species revealed that these native fishes have been extirpated from approximately half of their historic range, although they remain among the most widespread endemic desert fish species (Bezzerides and Bestgen 2002; Budy et al. 2015, Hoagstrom et al. 2021). These alarming declines resulted in the collaboration of state, federal and tribal agencies to create a range-wide conservation agreement that aims to develop conservation and management plans for these native fishes (Three Species Conservation Agreement and Strategy [TSCAS]: Utah Department of Natural Resources 2006). Many of the conservation actions that are outlined within the range-wide agreement are supported by assessing the movement patterns of three-species. For example, the TSCAS advises signatories to determine site specific population demographics, life history, habitat requirements and overall conservation needs (Utah Department of Natural Resources 2006). Each of these objectives can be addressed with information gathered from analyzing movement patterns and determining the spatial ecology of three-species within a specific location (Mueller and Fagan 2008; Rolls et al. 2013; Cooke et al. 2016).

The Dolores River basin, a sub-basin of the upper Colorado River drainage, is co-inhabited by each of the three species (Valdez et al. 1982). Prior to European settlement, three-species were presumed to be common and abundant throughout the Dolores River basin (Bezzerides and Bestgen 2002). Trans-basin diversions, the construction of McPhee Reservoir and Dam, and heavy uranium mining activity historically affected the health and status of three-species populations within the Dolores River basin (Nolting 1956; Valdez et al. 1982; Bestgen et al. 2011). There have been several studies and literature reviews that have described the current distribution and status of three-species throughout the main-stem rivers of the basin (Holden and Stalnaker 1975; Valdez et al. 1982, 1992; Bestgen et al. 2011). These studies, along with multiple reports prepared by Colorado Parks and Wildlife (CPW) have determined that the status of three-species is highly variable both spatially and temporally (D. Cammack, CPW, personal communication; Lower Dolores River Working Group 2014; Bestgen et al. 2011). However, these studies have principally focused on changes in catch-per-unit-effort, abundance, species composition and distribution through time, while the movement patterns and spatial ecology of three-species are rarely considered. In addition, many of the sampling events to assess the three-species fishery within the basin are conducted opportunistically, and standardized sampling is notoriously challenging to achieve because of highly variable flows and the remote nature of many sections of the river. Therefore, comparing data across years is difficult, which complicates assessments of the fishery (Lower Dolores River Working Group 2014). A significant lack of understanding of the movement patterns and spatial ecology of three-species that may account for the highly variable spatiotemporal distributions of these fishes within the Dolores River basin highlights the need for additional study. Using passive integrated technology, the movement patterns of three-species were investigated in an effort to advance the comprehension of the spatial ecology of these fishes within the Dolores River basin. The study had four main objectives: 1) Investigate the timing and magnitude of three-species movements; 2) Evaluate species-specific and site-specific differences in movement patterns; 3) Analyze three-species movement patterns to describe the spatial ecology and large-scale use of the basin; 4) Inform future management decisions regarding land and resource use in the basin. This study is the first to investigate movement patterns of three-species in the Dolores River basin. The additional insights this research yields will add to the knowledge of three-species life history traits, spatial ecology and conservation needs in one of the last remaining strongholds for these fishes.

Study Site

The Dolores River basin comprises the Dolores River and its main perennial tributary, the San Miguel River (Figure 1). The Dolores River is a major tributary to the Colorado River and encompasses a drainage of 4,600 mi^2 from its headwaters in the San Juan Mountains of Colorado to its confluence with the Colorado River in southeast Utah. The river flows for approximately 45 miles from the headwaters before entering McPhee Reservoir, at which point the river is inundated for 10 miles by the reservoir (Figure 1). Below the reservoir, the river continues for approximately 200 miles before reaching its confluence with the Colorado River. McPhee Dam is the only major barrier to fish movement along the main-stem of the Dolores River. The San Miguel River drains a 1,500 mi^2 drainage from its headwaters on the north side of the San Juan Mountain range and meets the Dolores River approximately 6 miles below the historic town of Uravan, Colorado. There are no major dams on the 81-mile length of the San Miguel River, though numerous diversions exist that influence the natural hydrograph, particularly during base flows. This study is limited to the 200 river miles below McPhee Reservoir in the Dolores River and 6 miles of the San Miguel River from Uravan to the confluence with the Dolores River.

The hydrology in the Dolores and San Miguel rivers is characterized by a snowmelt-driven runoff pattern, with peak discharge occurring in the spring and early summer, followed by low flows in the summer that are occasionally augmented by monsoon rain events. Both rivers flow through a wide range of habitat types, from broad-alluvial valleys to steep and constricted sandstone canyons.

Large portions of the perennial waters within the Dolores River basin are publicly owned and managed by the Bureau of Land Management (BLM). BLM-administered waters and adjoining lands within the basin are overseen by the Tres Rios Field Office, Uncompahgre Field Office, Moab Field Office and Grand Junction Field Office. Approximately half of the perennial river miles within the basin are managed by the aforementioned BLM field offices, which nearly doubles the number of river miles managed by all other state and federal agencies combined. Considering the substantial percentage of river miles that are BLM-managed, the management actions that BLM engages in are highly influential for the conservation of three-species.

A long and multifaceted history of water and land-use within the basin has caused major impacts to the Dolores and San Miguel rivers. Beginning in the 1880s, Dolores River water was diverted to the San Juan basin to provide an agricultural, industrial, and municipal water supply to the Montezuma Valley, CO. These diversions often left the Dolores River above the confluence with the San Miguel severely dewatered or entirely dry during low flow periods in the late summer and fall after spring peak flows subsided (Valdez et al. 1982; Dolores River Dialogue 2005). In 1984, the Dolores Project was completed, resulting in the impoundment of the Dolores River and the creation of McPhee Reservoir. Following the impoundment of the river, the magnitude and duration of peak flows downstream of the reservoir were severely diminished, while base flows were augmented slightly for the benefit of the fishery and downstream water users (Figure 2). Currently, the Dolores River between McPhee Reservoir and the confluence with the San Miguel River is still subject to a heavily modified flow regime that is characterized by reduced peak flows and relatively low base flows (Bestgen et al. 2011). This severance of the natural flow regime, particularly the reductions in high flows, has resulted in many adverse impacts to three-species habitats and biological processes (Dolores River Dialogue 2005; Lower Dolores River Working Group 2014). In contrast, the flow regime in the lower Dolores River is largely still intact because of flows deriving from the predominantly unregulated San Miguel River. Although the San Miguel River drains a lesser watershed (1,500 mi^2) when compared to the Dolores River (4,600 mi^2), the former regularly delivers twice as much flow than the latter because of a lack of main-stem dams that capture peak flows (Kowalski et al. 2007; Bestgen et al. 2011) (Figure 3). While the San Miguel River does maintain a more natural hydrograph that is reflected in the lower reaches of the Dolores River, historically the San Miguel River suffered from acute water quality issues. Rich deposits of uranium and vanadium ore in the benches above the lower reaches of the San Miguel River resulted in profuse mining activity from the 1930s to 1980s and the creation of the historic mining town of Uravan (Rood et al. 2008). Effluent from tailings ponds at several locations along the San Miguel River often discharged directly into the river, causing substantial water quality issues that resulted in fish kills and drastic fishery depletion (Nolting 1956; Holden and Stalnaker 1975; Valdez et al. 1992). Efforts to remediate the mining sites commenced in the late 1980s, when a court order stemming from the EPA Superfund Program was issued (Valdez et al. 1992).

Because of the large longitudinal extent and multitude of habitat types throughout the Dolores and San Miguel Rivers, these rivers are divided into different reaches for fish sampling purposes (Figure 4). In the upper portions of Dolores River #3A, within the first 30 miles downstream of McPhee Reservoir, cold-water releases have led to the establishment of a trout fishery and the extirpation of three-species (Bestgen et al. 2011). As water temperatures transition from cold to cool in the lower reaches of Dolores River #3A, three-species can be found in low abundances, although Roundtail Chub are generally more common than native suckers. Invasive Smallmouth Bass (*Micropterus dolomieui*) are also common in this reach, following a surface spill from McPhee Reservoir in 1993 that likely initially introduced the species downstream of the reservoir (Lower Dolores River Working Group 2014). As water temperatures become more favorable for three-species in Dolores River #2A and Dolores River #1, native sucker and Roundtail Chub abundances increase, particularly below the confluence with the San Miguel River (Kowalski et al. 2007). Despite the history of water quality issues and the subsequent diminished fishery in the San Miguel River, CPW personnel have recently found robust populations of three-species in the lower reaches of the river during spring longitudinal electrofishing surveys (D. Cammack, CPW, personal communication).

While three-species abundances and distribution are highly variable throughout the river basin, native species composition is consistently high both spatially and temporally. Many of the reaches that are sampled yield catches that comprise over 80% native species, a rarity among river basins within the Colorado River basin (Kowalski et al. 2007). A second unique and valuable characteristic of the Dolores River basin fishery is that non-native suckers are uncommon and have largely failed to become established (Mandeville et al. 2017), despite large abundances of the non-native fish both upstream in McPhee Reservoir (Bestgen et al. 2011) and downstream in the Colorado River and associated tributaries (McDonald et al. 2008; Quist et al. 2009). Of particular concern is the White Sucker (*Catostomus commersoni*) which readily hybridizes with native suckers, compromising their genetic integrity (McDonald et al. 2008; Quist et al. 2009; Bangs et al. 2018). Throughout all years of sampling within the Dolores River basin, very few White Suckers or associated hybrids have been documented (Bestgen et al. 2011,

J. White, CPW, personal communication). A final beneficial characteristic of the Dolores River basin from a native-fishery standpoint is the excellent longitudinal connectivity both within the basin and between the Dolores River basin and the upper Colorado River basin. McPhee Dam is the only major barrier to fish movement, allowing access to hundreds of river miles including access to the Colorado River. The only diversion structure on the main-stem of the Dolores River, Wines Diversion, is a river-wide, rock push-up dam that was constructed in 1900, located 27 miles upstream from the Dolores-Colorado River confluence (Figure 4). Wines Diversion may have been a historic barrier to fish movement under certain flow conditions, however, no analysis of passage efficiency for any species has ever been completed for the diversion (Wright Water Engineers 2017). High native species composition, low densities of non-native and hybrid suckers, and plentiful access to heterogeneous habitats both within and among river basins are characteristics that explain the significant conservation potential for three-species within the Dolores River basin.

Methods

Fish Capture and Tagging

Between 2013 and 2020, CPW, the BLM and Utah Division of Wildlife Resources (UDWR) personnel deployed passive integrated transponder (PIT) tags opportunistically into captured three-species during sampling surveys within the Dolores River basin to facilitate monitoring of three-species movements. In addition, UDWR deployed PIT tags in Flannelmouth and Bluehead suckers in the Colorado River near the confluence with the Dolores River in 2018. The 2018 UDWR Colorado River tagging effort was included in this analysis because of the unimpeded connectivity between the tagging reach and the Dolores River, and the tagged species are known to move long distances, thus there was a high probability that fish tagged in the Colorado River would be detected within the Dolores River basin. Data collected on captured three-species included weight (g), total length (mm), signs of sexual maturity (e.g. tubercles, milt or eggs) and the name of the capture reach. All capture data were entered into a PIT-tag database maintained by CPW for fish tagged in or near the Dolores River basin. Each fish was scanned with a portable handheld reader to check for pre-existing tags. Individuals ≥ 150 mm that had not yet received a PIT tag were implanted with a 12.1 x 2.1 mm, 134.2 kHz full-duplex PIT tag. Tags were inserted into the ventral surface of the fish, posterior to the left pelvic fin. Newly tagged fish were immediately returned to the river after processing was complete. Several studies have documented high PIT-tag retention rates and minimal tag-induced mortality for these species using similar tagging methods (Walters et al. 2012; Van Haverbeke et al. 2013; Hooley-Underwood et al. 2017).

Fish were captured using a variety of sampling techniques including backpack electrofishing, raft electrofishing, barge electrofishing, seining and hook-and-line sampling. The spatial and temporal distribution of PIT tags was highly inconsistent, as tagging efforts were entirely dependent upon agency sampling goals within a given year. Thus, quantitative comparisons of PIT-tag detections among years were limited because tagging efforts were not standardized. All sampling was done using proper handling techniques and using valid collecting permits authorized by CPW.

Fish Monitoring

Detections of PIT-tagged fish were collected on two Passive Interrogation Arrays (PIAs), each utilizing the IS1001 MTS system (Biomark, Boise, Idaho), which consists of a master controller and multiple pass-by, IS1001-compatible antennas. The IS1001 MTS system includes a Master Controller that stores PIT-tag detection data in an internal memory that is either downloaded to a removable memory device or communicated remotely to the BioLogic Site Module (Biomark, Boise, Idaho). Collected PIT-tag detection data includes a date-time stamp of each unique PIT-tag detection and the antenna on which the tag was detected. Each PIA spans the entire river channel and consists of two rows of several pass-by antennae that are anchored into the streambed. Rows of antennae are spaced several meters apart, creating downstream and upstream subarrays, which allows movement direction to be determined. The PIAs are located at the following points: the Rio Mesa Array (RMA) is in Utah, approximately 11.5 miles upstream from the confluence of the Colorado and Dolores rivers, and the Disappointment Creek Array (DCA) is 131 miles upstream from the confluence of the Colorado and Dolores rivers and approximately 54 miles downstream from McPhee Reservoir (Figure 4). The RMA was installed in 2013 to monitor fish communities in the lower Dolores River. Similarly, the DCA was installed in 2013 specifically to monitor three-species movements. This study was limited to analyzing the large-scale movement patterns of three-species within the basin because of the limited number of detection points (PIAs) and the substantial longitudinal expanse between the two arrays.

The RMA and DCA PIAs passively collected PIT-tag detection data beginning after installation in the late summer of 2013, however there were periods of time when the RMA was out of service because of solar panel issues. The RMA was out of service from October of 2013 through November of 2014, March 1st to March 20th of 2015 as well as August through October of 2015 and the entirety of 2018. The RMA was only operational from January to June in 2019, and from January to July in 2020. There were no recorded outages on the DCA throughout the entire study period, however, the oldest data were overwritten by newer data, thus detection data were available beginning in 2016 for the array.

Data handling and analysis

Stored PIT-tag detection data from each PIA were accessed for analysis in several different ways. On the RMA, stored detection data from 2015-2019 were accessed through the Species, Tagging, Research and Monitoring System (STReaMS) website (Colorado Natural Heritage Program 2018). STReaMS is a centralized interagency PIT-tag database, maintained by the Colorado Natural Heritage Program, that was developed to monitor the movements of PIT-tagged fishes and act as a repository for PIT-tag data in the upper Colorado River basin (Colorado Natural Heritage Program 2018). The online database preserves the PIT-tag detection data from many PIA locations throughout the upper Colorado River basin, as well as the capture data collected on fishes that are implanted with PIT tags. Users are able to query the database for the capture histories of individual PIT-tagged fish or the encounter histories on each PIA throughout the upper Colorado River basin.

Beginning in 2020, PIT-tag detection data from the RMA ceased to be uploaded to the STReaMS database. Thus, detection data from 2020 and 2021 were accessed via the BioLogic Site Module, which allows users to view PIT-tag detections on equipped PIA in near-real time using the web portal (Biomark, Boise, Idaho). PIT-detection data on the DCA were never uploaded to the STReaMS database. Instead, the stored detection data on the DCA from 2016-2019 were accessed through a physical download from the Master Controller internal memory. In 2020 and 2021, the detection data from the DCA were communicated to the BioLogic Site Module. How the detection data were accessed impacted data handling. When accessing detection data from the STReaMS database, all capture information for detected fish was retained, yet detection data accessed through a physical download or the BioLogic Site Module does not include capture information for each PIT tag detected. Thus, detection data accessed via the former two resources were merged with the CPW Dolores River basin PIT-tag database using Program R (R Core Team 2019, version 4.1.1). Tags that were detected that were not in the CPW PIT-tag database were searched in STReaMS to attempt to locate capture information associated with each tag. Detected tags that could not be located in the CPW PIT-tag database or the STReaMS database are referred to as unknown tags.

To assess the differences in detection magnitude on each PIA among years, the total number of unique tags detected per year at each PIA location, as well as the number of unique detections for each species were summarized. When summarizing the number of unique tags detected from each species, tags not associated with three-species were reported as other species, while tags that could not be identified in the CPW PIT-tag database or the STReaMS database were listed as unknown species. Only the first time each unique tag was encountered on the array each month was included for the annual unique detection analysis. The mean total length of tagged fish from each capture water that were detected on each PIA was calculated, as well as the mean total length of tagged fish that were never detected on either PIA, and those values were compared to identify possible size differences associated with detection or non-detection. The total length of detected or non-detected individuals was based on the total length at time of capture. The connectivity between the lower Dolores River and upper Dolores River was evaluated by investigating individuals that were detected on both the RMA and the DCA within the same year. Only the years when there was detection data for both PIA were considered for this portion of the analysis.

Differences in movement timing both among years and between PIA locations were analyzed for all three species grouped as well as for each species individually. The mean daily discharge at the nearest U.S. Geological Survey gauge station to each PIA was plotted along with numbers of unique PIT tags detected daily to visualize how detections may have been impacted by flows. To investigate the direction of movement associated with each PIT-tag detection event (upstream or downstream), the detection data were formatted to use the function “direction” in R package PITR (Harding et al. 2018). To confirm the functionality of the PITR package, a custom code was developed to compute movement direction associated with detections. The movement direction computation considered upstream or downstream movements only when a fish was detected moving from an upstream to downstream subarray (or vice versa) sequentially within the same day. In the cases when fish were not detected moving from upstream to downstream subarrays sequentially (or vice versa), the movement direction was returned as “unknown”.

To assess how tagged fish redistributed after receiving a tag, the percentage of three-species tagged in each capture reach that were later detected on either one of the PIAs was calculated. Finally, site fidelity rates were assessed by calculating the percentage of fish that were encountered in one year that were detected again in subsequent years at each PIA and for each species separately. All data analyses were conducted in the statistical software program R (R Core Team, version 4.1.1)

Results

Tagging and Detection Summary

From 2013-2020, CPW, BLM and UDWR completed a total of 40 sampling events within the study area that resulted in a total of 3,753 tags deployed into three-species individuals

(Table 1). Tagging efforts were concentrated in the San Miguel River, followed by Dolores River #2A and the Colorado River (Table 2). In 2020, the greatest number of tags were deployed (n = 878), followed by 2018 (n = 667) and 2017 (n = 625).

Of the 3,753 total individuals tagged, 3,101 were tagged within the Dolores River basin: Bluehead Suckers (758 tags; 268 mm TL, SE = 2.33), Flannelmouth Suckers (1,473 tags; 361 mm TL, SE = 3.31) and Roundtail Chub (870 tags; 194 mm TL, SE = 1.53) (Table 2). Additionally, 652 tags were implanted in Bluehead Suckers (250 tags; 296 mm TL, SE = 3.40) and Flannelmouth Suckers (402 tags; 426 mm TL, SE = 3.14) in the Colorado River near the confluence with the Dolores River (Table 2). A total of 1,279 (34%) of the tagged three-species individuals in the CPW PIT-tag database provided detection data on either the RMA or DCA. Seven percent (n = 247) of the three-species in the CPW PIT-tag database were detected on the DCA, while 31% (n = 1,175) were detected on the RMA. The RMA detected 25% (n = 193) of Bluehead Suckers, 41% (n = 607) of Flannelmouth Suckers and 8% (n = 73) of Roundtail Chub tagged in the Dolores River basin from 2014 to May of 2021, while 7% (n = 19) of Bluehead Suckers and 70% (n = 284) of Flannelmouth Suckers tagged in the Colorado River were detected on the RMA within the study period (Table 3). On the DCA, 2% (n = 16) of Bluehead Suckers, 7% (n = 99) of Flannelmouth Suckers and 10% (n = 89) of Roundtail Chub that were tagged in the Dolores River basin were detected, while 11% (n = 43) of the Flannelmouth Suckers and 0 of the 250 Bluehead Suckers tagged in the Colorado River were detected (Table 4).

Throughout the accessible record of detections on the RMA (2014-May 2021), there were a total of 2,072 unique tags encountered for all species aggregated, including unknown tags. From 2016-May 2021, there were a total of 273 unique tags detected on the DCA for all species aggregated, including unknown tags. The number of unique tags detected annually varied among years and between PIA locations, as well as the number of tags belonging to each species that were detected (Table 5). Since 2016, the number of unique tags detected annually has increased each year by nearly twice the amount as the previous year on the RMA (Table 5). On the DCA, the number of unique tags detected annually was variable, with the greatest number of unique detections occurring in 2017 (n = 95) and 2019 (n = 138) (Table 5). Unknown tag detections were generally low on both the RMA and DCA, however, in 2020 and 2021, there was a spike in unknown tag detections on the RMA, with 54 unknown tags detected in 2020 and 808 unknown tags detected as of May 2021 (Table 5). Many of the unknown tags detected in 2021 were likely Bonytail Chub (*Gila elegans*) that were stocked near the RMA, yet were not reported to STReaMS prior to this analysis to allow confirmation of identity.

The number and percentage of unique individuals detected at each array that were tagged in each capture water varied by array. Relatively large numbers of fish detected on the RMA were tagged in the San Miguel River (n = 310), Colorado River (n = 303) and Dolores River #2A (n = 222) (Table 7). The greatest number of three-species that were detected on the DCA were tagged in Dolores River #3A (n = 104), Dolores River #2A (n = 72) and the Colorado River (n = 43). Bluehead Suckers detected at the RMA were primarily tagged in the San Miguel River (n = 109) and Dolores River #2A (n = 42) (Table 3). Flannelmouth Suckers had relatively high numbers of individuals that were detected from each capture water, with the greatest numbers of individuals detected tagged in the Colorado River (n = 284), Dolores River #2A (n = 191) and the San Miguel River (n = 188) (Table 3). Roundtail Chub were less frequently detected on the RMA when compared to the native suckers, yet the highest numbers of individuals detected were tagged in Dolores River #1 (n = 19), Dolores River #2A (n = 22) and the San Miguel River (n = 13) (Table 3). For every species and every capture water, the mean size of fish detected on the

RMA was greater than the mean size of tagged fish that were never detected (Table 3). On the DCA, very low numbers of Bluehead Suckers were encountered, yet the highest number of individuals detected were tagged in the San Miguel River (n = 6), followed by individuals tagged in Dolores River #3A (n = 5) (Table 4). Flannelmouth Suckers detected on the DCA were primarily tagged in Dolores River #3A (n = 47), Dolores River #2A (n = 39) and the Colorado River (n = 39) (Table 4). The greatest number of Roundtail Chub that were detected on the DCA were tagged in Dolores River #3A (n = 52) and Dolores River #2A (n = 31). Similar to the fish detected on the RMA, mean sizes of three-species detected on the DCA were generally larger than mean sizes of three-species that were not detected (Table 4).

Analyzing the numbers of each species tagged each year that were encountered in subsequent years revealed that detections of each species on both arrays were generally the highest one to two years after tagging (Table 7). However, on the DCA, detections of each species were found to be highest in the same year as tagging during several years of the study (Table 8). There was a high percentage of individuals that were detected at both PIA locations, as 58% of the individuals encountered on the DCA were also encountered on the RMA (n = 159 of 273). Native suckers that were detected on the DCA were especially likely to have detection records on the RMA. The data showed that 82% (n = 118 of 144) of Flannelmouth Suckers and 50% (n = 10 of 20) of Bluehead Suckers detected on the DCA were also detected on the RMA. Comparatively, Roundtail Chub were less frequently encountered at both PIA locations, as 19% (n = 17 of 89) of the individuals detected on the DCA were detected on the RMA. In years when there was a relatively high number of Flannelmouth Sucker detections at both PIA locations (2017, 2019 and 2020), there were a notable number of individuals that were detected at both locations within the same year. In 2019, 61 Flannelmouth Suckers were detected at both PIA locations and in 2020, 23 were detected at both PIA locations (Table 9). Flannelmouth Suckers that were detected at both PIA locations within the same year were always detected at the RMA prior to being detected at the DCA. It took Flannelmouth Suckers an average of 83 days (SE = 9.94) to travel the approximately 120 river miles between the two PIA locations in 2017, 52 days (SE = 1.36) in 2019, and 30 days (SE = 1.80) in 2020. Only Roundtail Chub were detected on the DCA prior to being detected on the RMA within the same year, a particular movement pattern that was only observed in 2017. In 2020, there were eight Roundtail Chub encountered on the RMA prior to encountering the DCA, and those individuals took an average of 51 days (SE = 7.71) to travel between the two PIAs.

Timing and Directions

Across all years of detection data, detections of PIT-tagged fishes on the RMA peaked in March and early April, after which numbers of tag detections dropped considerably (Figure 5). Detections in the spring typically were associated with upstream movements when using the PITR package, as well as the code developed to compute movement direction. A major discrepancy in the movement directions of detected fishes using the PITR package and developed code was seen in the 2020 data, when PITR identified a series of upstream and downstream movements within the same day, while the developed code identified these movements as unknown movement directions. Otherwise, both methods of determining movement direction were mostly concordant. Downstream movements were rarely identified on the RMA, however when they were identified, they typically occurred in the late summer to fall. In 2015 and 2016, the peak of spring detections in March and April corresponded to Bluehead Suckers, while from 2017-2021 the peak of spring detections were Flannelmouth Suckers

(Figure 6). Although Roundtail Chub were not frequently detected at the RMA, many of the individuals detected were encountered in the spring months, similar to the native suckers. Each year, peak detections occurred prior to peak discharge when flows were still below 500 cfs (Figure 7). Detections were rare outside of the spring detection period.

On the DCA, the peak of detections was less defined and more variable when compared to the RMA. Fish began to be detected at the array starting in April each year. In 2018 and 2020, there was a defined peak of detections in April, while in 2016 and 2019 there was a peak of detections in May rather than in April (Figure 8). In 2017, fish were not detected in high numbers until June and the peak of detections did not occur until July. Summer and fall movements were more frequent on the DCA when compared to the RMA and generally the timing of movements were later in the year. Determining movement directions for detected fish proved to be difficult on the DCA because fish frequently spent long periods of time on the array, moving between upstream and downstream subarrays many times before moving off the array. What the PITR package characterized as a combination of upstream and downstream movements, my code identified as unknown final movement directions (Figure 8). Detections in the spring and early summer were associated with Flannelmouth Suckers and Bluehead Suckers, while the movements of Roundtail Chub were more concentrated in the late summer and fall (Figure 9). Flows on the Dolores River above the confluence with the San Miguel River are largely dependent upon releases from McPhee Reservoir, therefore flow timing and magnitude were highly variable throughout the study (Figure 10). In 2017 and 2019, the Dolores River experienced large managed releases from McPhee Reservoir. The release in 2017 resulted in peak flows in May, while the release in 2019 resulted in peak flows in late June. All detections in 2017 occurred after peak flows had subsided. In 2019, there was a peak of detections prior to peak flows as well as immediately following peak flows. In years characterized by lower than average flows (2018 and 2020), there was a peak of detections in April and lower numbers of daily detections carried on throughout the rest of the year. In 2016, a year with slightly higher than average flows, fish began to be detected in late April and high numbers of detections ceased by mid-June.

Site Fidelity

Out of the 1,279 aggregated unique three-species detections on the Rio Mesa and Disappointment Creek arrays, 48% percent (n = 615) were detected in more than one year. Of the 615 fishes that were detected in multiple years, 499 (81%) were Flannelmouth Suckers, 74 (12%) were Bluehead Suckers and 42 (7%) were Roundtail Chub. Thirty-one percent (n = 1,175) of three-species in the CPW PIT-tag database were detected on the RMA (Table 9). A large percentage of the three-species detected on the RMA were detected in more than one year (n = 540, 46%). Of the 540 fishes detected in more than one year on the RMA, the majority were Flannelmouth Suckers (n = 458, 85%), followed by Bluehead Suckers (n = 65, 12%) and Roundtail Chub (n = 17, 3%). Seven percent (n = 247) of three-species tagged for this study were encountered on the DCA (Table 9). Of the 247 individuals encountered at the DCA, 66% percent (n = 164) were encountered in multiple years. Similar to the RMA, Flannelmouth Suckers had the highest number of individuals detected across multiple years (n = 97, 59%), followed by Roundtail Chub (n = 56, 34%) and Bluehead Suckers (n = 11, 7%). Flannelmouth Suckers had the greatest number of individuals detected multiple years in a row on the RMA, with 13% (n = 116 of 890) being detected three consecutive years and several individuals detected 4 and 5 consecutive years when excluding the year of missing data in 2018 (Table 10). While Bluehead

Suckers and Roundtail Chub did have individuals returning two years in a row on the RMA, the numbers of individuals returning three years in a row for both species were low. Although the percentage of Roundtail Chub returning for two consecutive years to the DCA was the lowest when compared to the native suckers, the species had the highest number of individuals that were detected both three and four consecutive years (Table 10).

Discussion

Using passive integrated technology, the understanding of the large-scale use of the Dolores River basin by three-species was increased and dominant movement patterns of the sensitive fish assemblage at disparate points in the Dolores River were identified. Four main findings gathered from the results are summarized. 1) There are high levels of connectivity both within the Dolores River basin and between the Dolores River basin and the Colorado River; 2) A portion of the three-species populations make annual migrations to the Dolores River basin; 3) Passive integrated technology is an efficient method to study three-species movements and large-scale use of the Dolores River basin; 4) Site fidelity at both PIA locations was moderately high, though there were species-specific and site-specific differences. Each of these findings are discussed in more detail below. Moreover, the implications that these results have for the management of the three-species fishery are discussed.

Connectivity

Perhaps one of the most significant findings from this study is the demonstration of the broad dispersal capability that three-species exhibit in the Dolores River basin, as well as evidence of the excellent connectivity among reaches within the basin, and between the Dolores River and the Colorado River. This broad dispersal capability was highlighted by the large number of detections of three-species on the RMA that were tagged in the San Miguel River and Dolores River #2A sampling reach, particularly the native suckers. Fish tagged in Dolores River #2A were tagged at the least 65 miles away from the RMA, while fish tagged in the San Miguel River reach were tagged at least 55 miles away. Nearly half of the native suckers tagged in each of these reaches were encountered on the RMA in the years following tagging, indicating the importance of maintaining connectivity within the Dolores River basin, and documenting that the native suckers inhabiting those reaches are highly mobile. The highly mobile nature of the native suckers suggests that a portion of the individuals inhabiting each reach may only be using the habitats present in each reach seasonally, and portions of the native sucker populations are migratory rather than sedentary within a small home range (Skalski and Gilliam 2000; Radinger and Wolter 2014). Alternatively, these movements could indicate that native suckers tagged in each of these reaches have large home ranges that include the main-stem rivers in the Dolores River basin in addition to the Colorado River.

These data indicate high levels of connectivity between the Colorado River and the Dolores River, as many of the native suckers tagged in the Colorado River reach were detected on the RMA, particularly Flannelmouth Suckers. There were relatively few individuals detected on the DCA, yet nearly 20% of the total unique detections were of Flannelmouth Suckers tagged in the Colorado River, further highlighting the connectivity between the Colorado River and the upper reaches of the Dolores River. The connectivity between the lower Dolores River and upper Dolores River was also emphasized by three-species that were detected at both PIA locations. Even more striking was the finding that each of the three species have detection records at both PIA locations within the same year, providing empirical evidence of the ability of each species to navigate the Wines Diversion structure and presenting the importance of maintaining connectivity throughout the entire Dolores River drainage.

The overall number of unique detections on the DCA were highest in 2017 and 2019, years when managed releases from McPhee Reservoir occurred. This suggests that functional connectivity within the Dolores River is enhanced by the more natural flow regime realized when Dolores River flows captured in McPhee Reservoir are released and that each of the three species utilize large expanses of the basin when flows allow. Similarly, Cathcart et al. (2015) and Fraser et al. (2017) demonstrated how increased flows benefit three-species and increase the functional connectivity within river networks. Surprisingly, even in 2020, when flows in the Dolores River above the San Miguel River confluence never exceeded 100 cfs, Flannelmouth Suckers and Roundtail Chub were documented making an approximately 120-mile movement between the RMA and DCA. These long-distance movements indicate that there is a distinct migration corridor spanning large portions of the Dolores River below McPhee Dam, even during periods of relatively low flows. In order for migrations of three-species to continue through this corridor, adequate flows must be released during the migration period (Utah Department of Natural Resources 2006). Only a fraction of the water stored in McPhee Reservoir is allotted for the downstream fishery, yet perhaps the allotted water should be used to maintain migratory corridors during the migration period rather than maintaining base flows during a period when the migration is over.

The connectivity that has enabled migrations may be an important factor that has allowed three-species to persist in the Dolores River basin despite a history of intense dewatering and extremely poor water quality. Nolting (1956) and Valdez et al. (1992) reported that effluent discharged from uranium processing facilities resulted in severe fishery depletions in the lower

60 miles of the Dolores River and 6 miles of the San Miguel River downstream of Uravan from 1955 through the mid-1960s. These fish kills occurred concurrently with severe dewatering in the Dolores River above the confluence with the San Miguel River in the late summer and fall (Valdez et al. 1982). For these reasons, it can be reasonably assumed that large portions of the Dolores River basin at the time were inhabited by very few fish, including three-species. However, by 1971, three-species were reported to be common near Gateway, Colorado, in the lower Dolores River (Holden and Stalnaker 1975). This emphasizes the ability of three-species to recolonize habitat affected by dewatering or anthropogenic disturbances, provided that water quality is sufficiently good, and adequate connectivity to source populations is maintained (Utah Department of Natural Resources 2006). Hence, maintaining connectivity should be a priority for fisheries managers, especially considering that prolonged drought and subsequent dewatering are projected to become more common in the southwestern United States due to climate change (MacDonald 2010). Maintaining connectivity can allow severely dewatered reaches that could experience fish kills, such as the Dolores River above the confluence with the San Miguel River, to be recolonized during wetter periods (Bower et al. 2008).

The findings from this study have emphasized the importance of the San Miguel River for the conservation of the three-species populations in the Dolores River basin. The relatively unregulated river is essential for delivering flows to the lower Dolores River that drive geomorphic processes that are important for maintaining suitable habitats for three-species (Poff et al. 1997; Bezzerides and Bestgen 2002; Dolores River Dialogue 2005; Bower et al. 2008). Consequently, high abundances of three-species are frequently found in the lower San Miguel River and the Dolores River below the confluence with the San Miguel River (Dolores River Dialogue 2005; Bestgen et al. 2011; Lower Dolores River Working Group 2014). In addition, many of the three-species captured in the lower San Miguel River during spring sampling surveys are reproductively mature, indicating that there are likely adequate spawning habitats located within the river. The finding that large numbers of three-species tagged in the San Miguel River were later detected on the RMA moving in an upstream direction also suggests that the San Miguel River may contain critical habitats for fishes exhibiting migratory movements. The flows of the lower Dolores River are largely dependent on flows from the San Miguel River, thus perennial connectivity among the Colorado River and the Dolores River basin is often maintained by flows contributed by the San Miguel River. Finally, tributary rivers that have intact flow and thermal regimes are known to be important for the functioning of large river ecosystems, especially in situations where main-stem habitats are highly altered (Pracheil et al. 2009). For these reasons, this study illustrates that protecting and maintaining the natural flow regime of the San Miguel River is essential for the continued persistence of the native fishery, and that the San Miguel River has high conservation value for these species. State and federal natural resource and wildlife management agencies should pursue opportunities to acquire additional instream flows to protect the natural flow regime of the San Miguel River and limit any additional proposed water storage projects whenever possible. Land-use practices that contribute to sedimentation should also be limited, as they could adversely affect three-species spawning habitats that are likely present in the San Miguel River. A final management consideration regarding the San Miguel River is that three-species have only been tagged in the lower six miles of the river. Sampling and tagging fish in upstream reaches and later detecting those tagged individuals could contribute to identifying critical habitats and further illuminate the importance of the San Miguel River for the Dolores River basin native fishery.

Along with protecting the natural flow regime of the San Miguel River, the redesign of the Wines Diversion structure also has significant implications for affecting connectivity between the Dolores River and Colorado River. Given the known adverse effects of fragmenting riverscapes for mobile fish species, the redesign of the Wines Diversion structure should be carefully and thoughtfully considered to avoid fragmenting three-species populations and disrupting metapopulation dynamics (Dingle 1996; Fausch et al. 2002; Compton et al. 2008). Certainly, a fish passage component needs to be incorporated into the redesigned Wines Diversion structure to maintain connectivity and facilitate three-species movement both throughout the Dolores River basin and between the Dolores River and Colorado River. However, maintained or enhanced connectivity may allow the invasion of non-native species that are common in the Colorado River but have yet to invade the Dolores River drainage *en masse* (McDonald et al. 2008; Underwood et al. 2014). The invasion of non-native suckers that hybridize with native suckers is of particular concern, especially considering that the abundances of non-native suckers and associated hybrids are still relatively low in the Dolores River basin and that non-native suckers are also known to make upstream spawning migrations (Sweet and Hubert 2010). Given that there is considerable overlap in swimming performance among three-species and non-native suckers, it will not be possible to design a fish-passage structure that will exclude non-native suckers while allowing passage for three-species (Underwood et al. 2014). For these reasons, managers should seriously consider employing a trap-and-sort fishway to allow for three-species movement, while simultaneously ensuring non-native suckers and associated hybrid swarms do not become established in the Dolores River basin. Although a trap-and-sort fishway may be economically burdensome for management agencies, the costs associated with a trap-and-sort fishway are miniscule compared to the costs of attempting to eradicate non-native suckers and associated hybrids if they do become established. Further, the data indicate that peak migration and movements of three-species at the Wines Diversion structure will occur primarily in March and April. Thus, a trap-and-sort fishway may only need to be manned during these peak migration months, cutting the costs of needing to man the fishway continuously. Non-native suckers are established in McPhee Reservoir, thus there is a threat of invasion from upstream sources as well, yet this is a threat that can be minimized with careful water release management and spillover prevention.

Maintaining connectivity for native suckers while simultaneously preventing non-native suckers from becoming established has significant implications for the conservation of Flannelmouth Suckers and Bluehead Suckers in the Dolores River basin and conceivably for these species in the entire upper Colorado River basin. These PIA data show that hundreds of native suckers are migrating into the Dolores River in the spring, presumably to spawn. Non-native suckers are still relatively uncommon in much of the Dolores River basin and have not yet become established. This means that native suckers may be able to spawn in habitats lacking non-native suckers and contribute non-hybrid progeny back to the Dolores and Colorado rivers. Considering that hybridization is a substantial threat to the persistence of Flannelmouth and Bluehead Suckers, any habitats that lack non-native Catostomids have high conservation value (Bezzerides and Bestgen 2002; McDonald et al. 2008; Quist et al. 2009). It is still uncertain as to why non-native suckers have not become established in the Dolores River basin, which is a topic that should be of keen interest to three-species managers and researchers.

Large-Scale Movement Patterns

Distinct annual migratory movements of adult three-species individuals into the Dolores River basin were documented through investigating detection records on the RMA. Tagged adults of all three-species moved upstream into the Dolores River during March and April in each of the years with available detection data, suggesting that portions of the three-species populations are migratory. More specifically, hundreds of Flannelmouth and Bluehead suckers were documented migrating into the Dolores River, consistent with other studies that have found migrations of these species from main-stem habitats to tributary habitats (Weiss 1998; Cathcart et al. 2017, Fraser et al. 2017; Hooley-Underwood et al. 2019). Hooley-Underwood et al. (2019) documented thousands of Bluehead Suckers and hundreds of Flannelmouth Suckers migrating into Cottonwood Creek, an intermittent tributary of the Gunnison River, CO, while Cathcart et al. (2017) documented thousands of Flannelmouth Suckers entering McElmo Creek, a perennial tributary to the San Juan River, UT. These numbers of either native sucker species were not documented entering the perennial Dolores River, however, this could be because roughly half the number of tags were deployed in this study when compared to the aforementioned studies. Numbers of three-species that are making annual migrations to the Dolores River are likely grossly underestimated, as only a very small portion of the total number of three-species that make this annual migration are tagged, as evidenced by a low physical recapture percentage (< 1%). Continuing to deploy PIT tags will be useful to more accurately quantify the numbers of three-species that are exhibiting these migratory movements. The proportion of individuals that exhibit migratory versus sedentary movement behaviors are unknown based on these data; however, these data suggest that fish size may be an explanatory variable for migratory movement behavior.

Interestingly, the timing of the migratory movement was relatively stable among years despite the high variability in discharge. In addition, there appeared to be no difference in timing of movements among each of the three species on the RMA, however the timing of movements of Roundtail Chub would have been clearer if a greater number of individuals were detected. The timing of these movements is indicative of spawning movements, as the peak detection period was just prior to the known spawning season of three-species (Bezzerides and Bestgen 2002; Bestgen et al. 2011). Moreover, similar spawning migrations of three-species from main-stem rivers into tributaries elsewhere in the upper Colorado River basin are increasingly well-documented (Compton et al. 2008; Cathcart et al. 2015; Fraser et al. 2017; Hooley-Underwood 2019). Three-species detected moving into the Dolores River in the spring presumably overwinter in the Colorado River, which can be reasonably inferred because of the large number of fish tagged in the Colorado River in August of 2018 that were not detected on the RMA until the spring of 2019. This apparent annual immigration of three-species from the Colorado River to the Dolores River has important implications for maintaining metapopulation dynamics, enabling genetic exchange and facilitating the completion of life cycles (Nathan et al. 2008; Cooke et al. 2016; Cathcart et al. 2019). Further, the knowledge that large numbers of adult three-species move upstream into the Dolores River in the spring increases the understanding of the spatiotemporal distribution of these fishes in the Dolores River. The knowledge of when three-species are likely to be present at different locations throughout the basin, as well as the movement corridors used, can be used to develop more effective and efficient sampling plans (Cooke et al. 2016).

Similar migratory movements were documented for Flannelmouth and Bluehead suckers on the DCA, although the magnitude and timing of use differed. Relatively few native suckers were detected on the DCA when compared to the RMA and this trend was especially pronounced for Bluehead Suckers. The low number of Bluehead Suckers detected on the DCA suggests that there may not be suitable habitats for the species in the upper Dolores River, a conjecture that is supported by other studies (Bestgen et al. 2011, Lower Dolores River Working Group 2014). The shift of native sucker peak movements to April and May on the DCA, compared to March and April on the RMA, could be explained by the long distances migratory suckers travel from winter habitats to reach the DCA. Alternatively, the difference in movement timing at each PIA could be explained by differences in abiotic factors at each PIA that cue three-species migrations such as temperature and discharge (Weiss et al. 1998; Bezzerides and Bestgen 2002; Cathcart et al. 2017; Fraser et al. 2017), however these factors were not addressed herein. Unlike the RMA, there were species-specific differences in movement timing on the DCA, as the peak of Roundtail Chub detections were typically in June and July, overlapping the known spawning season of the species (Kaeding et al. 1990, Bezzerides and Bestgen 2002). There were also numerous individuals that were detected in the fall, outside of the known spawning season of Roundtail Chub, which could be attributed to a search for adequate winter habitat. This hypothesis is supported by Siebert (1980) who documented the seasonal movement of Roundtail Chub between valley and canyon reaches in Aravaipa Creek, Arizona. Knowledge of the migrations of three-species into the Dolores River basin and the movements within the basin has greatly increased the understanding of the life history requirements of Dolores River basin three-species populations. Acquiring this knowledge is one of the critical conservation actions outlined by the TSCAS (Utah Department of Natural Resources 2006) and one of monitoring objectives developed by the Lower Dolores River Working Group (2014).

These data are useful for documenting likely spawning migrations of three-species into the Dolores River basin, however, there is still a dearth of information regarding specific spawning sites that three-species are utilizing within the basin. Identifying critical spawning sites should be a significant research and monitoring objective for fisheries managers. Establishing known spawning habitats is not only important so that such sites can be protected or enhanced, it also enables similar sites to be replicated elsewhere within the basin. Identifying critical spawning sites could be accomplished through pairing passive integrated technology with larval drift surveys to identify sites within the basin that are frequently visited by tagged fishes and confirming spawning at those locations. Additional PIAs, SPRs, or a combination of the two are needed to provide the fine-scale movement and detection data required to identify critical spawning sites.

Although the annual one-way migration of three-species was frequently observed, documenting out-migration of individuals into the Colorado River was rare. Poor detection efficiency of fish moving in the downstream direction was the apparent cause, supported by the observation that many fish detected multiple years moving upstream at the RMA were never detected moving downstream. This supposition is supported by studies that reported decreased detection efficiency of PIT-tagged fish on PIA based on movement direction, environmental conditions, and fish swimming behavior (Zydlewski et al. 2006; Aymes and Rives 2009). Because detection efficiency was so low for fish moving in the downstream direction, the residency duration of migrating three-species could not be computed. Future movement studies within the basin should evaluate the detection efficiency of each PIA to identify factors that are contributing to decreased detection efficiency and perhaps make improvements to each PIA to increase detection efficiency. For example, enhanced detection efficiency at the RMA would increase the probability of documenting out-migrations of three-species to the Colorado River. Such information would be useful for understanding the duration that migrating three-species use the Dolores River basin, filling knowledge gaps regarding life history requirements and the spatiotemporal distribution of these fishes.

Utility of PIAs

This study highlighted the utility of PIA systems for describing the large-scale use and movement patterns of this highly mobile fish assemblage. Throughout all 40 sampling surveys where three-species individuals were tagged (Table 1), only 40 PIT-tagged fish were actively recaptured, while comparatively 1,279 PIT-tagged individuals were detected on the PIAs. Continuously monitoring three-species movements is especially useful in the Dolores River basin where routine and standardized sampling surveys are notoriously difficult to achieve because of lack of flows and the remote nature of many of the reaches (Lower Dolores River Working Group 2014). The findings from this study correspond to the findings of other studies that have demonstrated the utility of PIA systems and remote monitoring for studying the movements of highly mobile and migratory sensitive and endangered fishes (Bottcher et al. 2013; Cathcart et al. 2017; Fraser et al. 2017; Pennock et al. 2020). A second major advantage of utilizing passive integrated technology to study three-species movement patterns is that each species has a relatively long lifespan and low annual mortality rates, which means tagged fishes may provide recapture data for many years after tagging (Bezzerides and Bestgen 2002; Klein et al. 2017). Additionally, establishing baseline data on three-species movement patterns using PIAs is useful for documenting changes in movement patterns and effectiveness of conservation actions. Collection of these baseline data and developing and maintaining such data sets is one of the conservation actions outlined by the TSCAS (Utah Department of Natural Resources 2006). Thus, it is important to continue to monitor three-species movement patterns and to compare future findings to current patterns documented in this study to determine if management actions are effective or if they should be adapted.

Although remote monitoring proved to be an effective way to increase recapture data of tagged three-species, there are several obstacles and limitations associated with passive integrated technology that need to be considered. First, remote monitoring produces large and complex datasets which require considerable time and effort to manage and analyze (Cooke et al. 2016). Managers that plan on incorporating remote monitoring data into three-species research in the Dolores River basin in the future should be aware of the complexity of the data and the time and knowledge it will take to manage and compile detection datasets. This complexity was highlighted when attempting to determine movement direction of fish at each antenna array. Final movement direction proved to be difficult to determine in many cases because of the movement behavior of fishes as they encountered the array, especially on the DCA. Fish detected on the DCA frequently "sat" on the array for long periods of time, moving between upstream and downstream subarrays recurrently, thus final movement directions were difficult to determine. Managers should be aware that determining movement direction can be difficult and custom codes will need to be developed for accurate determination of final movement directions on PIA.

Second, there needs to be more interstate and interagency collaboration regarding uploading PIT-tag data to the STReaMS database and regularly updating the database. Because the STReaMS database has not been regularly updated with both capture data associated with deployed PIT-tags and PIA-detection data, a CPW PIT-tag database needed to be created and maintained independent of the STReaMS database. Although the CPW PIT-tag database is highly functional for identifying detected individuals associated with PIT-tags deployed by CPW and the BLM in the Dolores River basin, it can not be used to identify detected "unknown" individuals that were tagged by agencies outside of the Dolores River basin. The sharp increase of "unknown" tags detected at the RMA in 2020 and 2021 that could not be identified in the STReaMS database highlights the need for more timely and faithful submission of PIT-tag data to the STReaMS database on behalf of the agencies deploying PIT tags, as well as an effort to regularly update and maintain the database on the behalf of STReaMS system adminstators.

Third, the RMA and DCA were over 120 miles apart, making the spatial resolution of the detection data relatively coarse. Although this resolution was useful for providing information on ecological processes that span large spatial extents (i.e. migration), additional PIA placed in the main-stem of the Dolores and San Miguel rivers would provide finer-scale spatial information on three-species movements that would be valuable for identifying critical habitats, evaluating connectivity, assessing dispersal capability and investigating population dynamics (Cooke et al. 2016; Fraser et al. 2017). It should be noted that additional PIA will add to the complexity of movement data and the time and effort needed to manage and analyze the data. Therefore, managers responsible for monitoring and conserving three-species should consider exploring other methodologies that can answer questions regarding population connectivity and spatiotemporal distributions of fishes, such as otolith chemistry and genomic approaches (Cooke et al. 2016).

Site Fidelity

These data showed the consecutive detections of individual three-species across several years of the study on both the RMA and DCA, suggesting that these species are exhibiting some level of annual site fidelity, perhaps driven by homing behavior that has been suggested for Catostomids (Fraser et al. 2017; Hooley-Underwood 2019; Cathcart 2021). Bluehead Suckers and Flannelmouth Suckers each had numerous individuals that were detected at least two years in a row on the RMA and over 100 Flannelmouth Suckers were detected three years in a row. The repeated use of the Dolores River suggests that there are desirable habitats within the Dolores River basin that native suckers access annually. However, because of the limited detection points in this study, the specific habitats that are being accessed annually are unknown and warrant further investigation. On the DCA, each of the three-species had individuals detected two years in a row, however these repeat occurrences were much higher for Roundtail Chub and Flannelmouth Sucker. There are known to be high abundances of Roundtail Chub inhabiting the Dolores River near the DCA, yet Flannelmouth Suckers are reported to be rare in the upstream reaches of the Dolores River (Bestgen et al. 2011). As such, it was surprising that nearly 150 Flannelmouth Suckers were detected on the DCA, as well as individuals that returned two and three years in a row. Multiple returns of Flannelmouth Suckers to the DCA may indicate that suitable habitats still exist in the upper reaches of the Dolores River and therefore should not be considered uninhabitable for the species. The specific habitats that Flannelmouth Suckers are selecting in the upper Dolores River cannot be identified with these data and should be investigated further with current habitat suitability studies.

Conclusion

The Dolores River basin has a long and complex history of water development and land use that has produced adverse conditions for three-species, yet the native fish assemblage has been able to persist within the basin. This persistence may be attributed to inter- and intra-basin connectivity, diverse life history strategies of three-species and a relatively unregulated tributary amidst a highly regulated main-stem river. Three-species have been notoriously difficult to study within the Dolores River basin, yet the large-scale use and movement patterns of these species have been described in this study by utilizing passive integrated technology, a tool that has proved to be fundamental in studying and understanding the movement ecology of the Dolores River basin three-species assemblage. While many recommendations for future research needs have been provided, several practical management actions that can be taken are outlined to guide towards the continued persistence and conservation of one of the last remaining three-species strongholds.

Figures and Tables

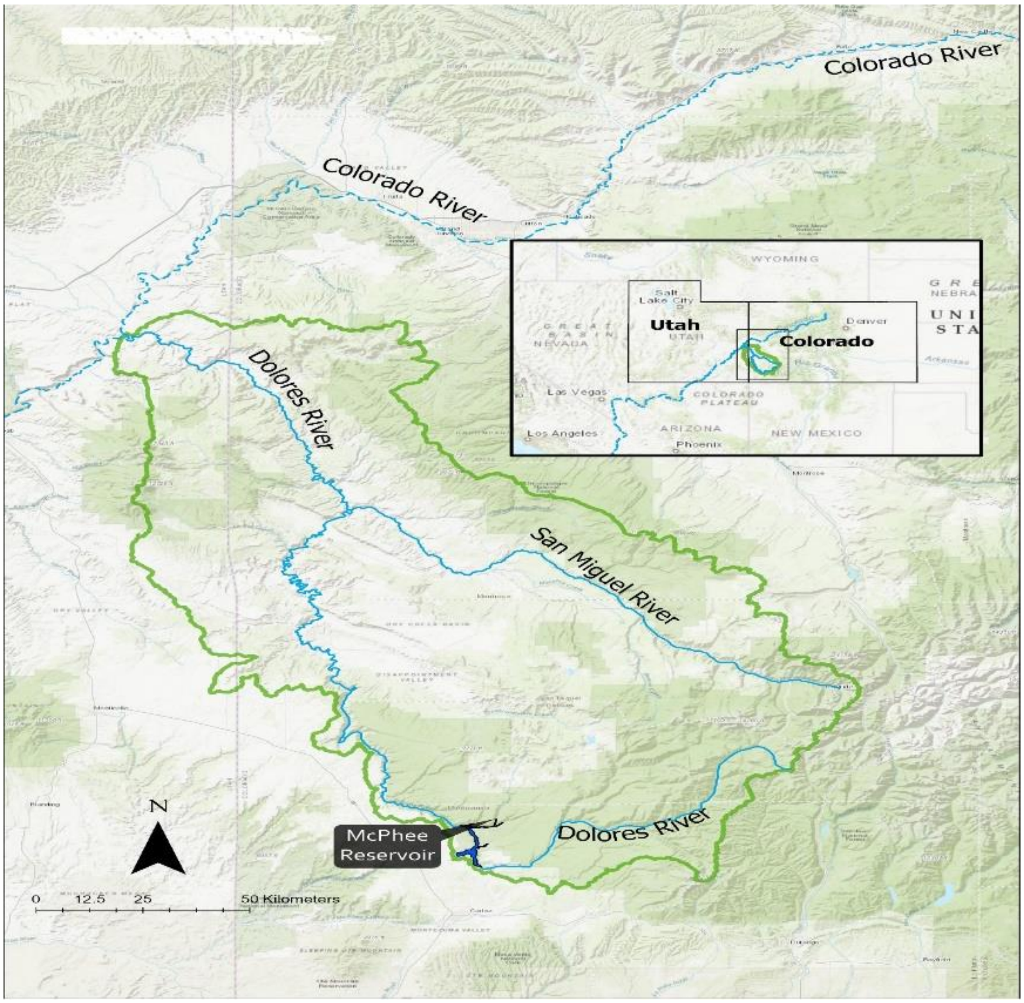

FIGURE 1. The Dolores River basin, southwestern United States, highlighting the location of McPhee Reservoir

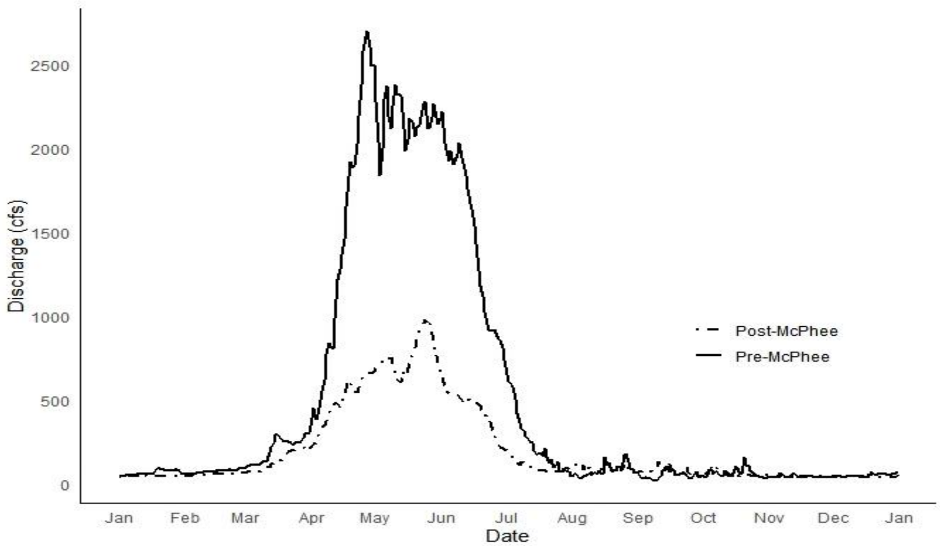

FIGURE 2. Mean daily flow of the Dolores River at Bedrock (U.S. Geological Survey gauge 09169500) prior to the creation of McPhee Reservoir (Pre-McPhee; period of record: 1972-1986) and after the creation of McPhee Reservoir (Post-McPhee; period of record: 1987-2020)

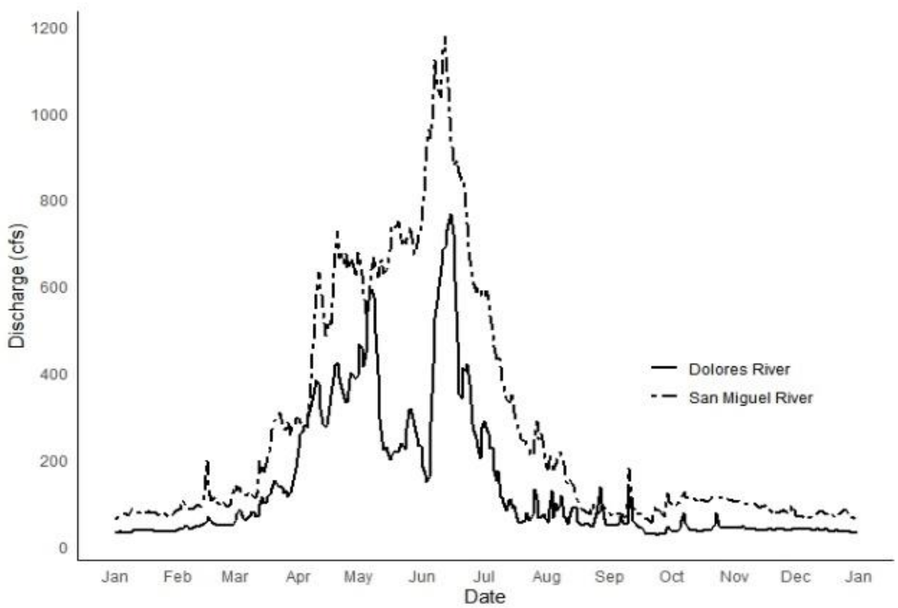

FIGURE 3. Mean daily flow (cfs) of the Dolores River at Bedrock (U.S. Geological Survey gauge 09169500) and the San Miguel River at Uravan (U.S. Geological Survey gauge 09177000) for the study period (2014-2020).

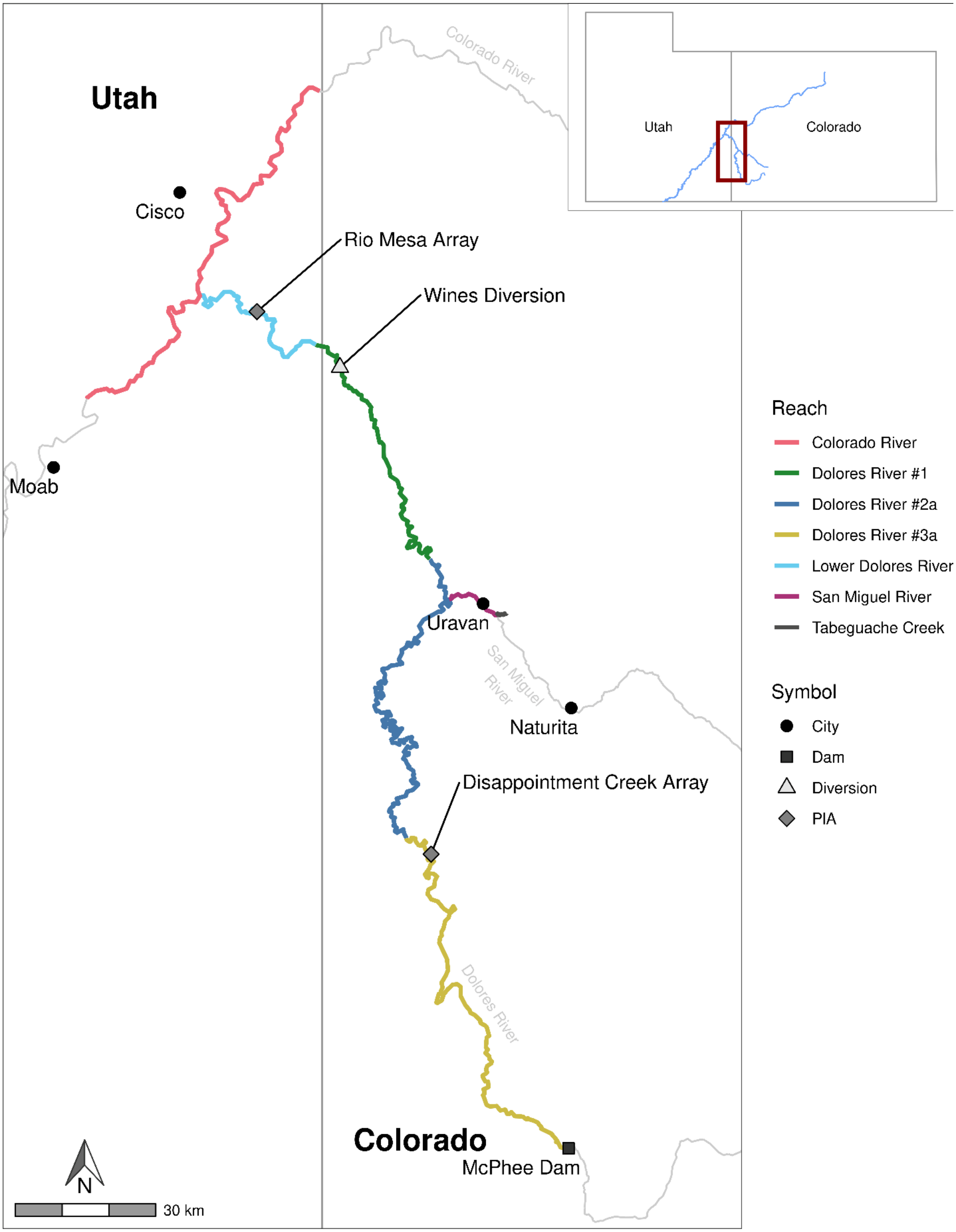

FIGURE 4. Map of the study area broken down by capture reaches. Positions of the Rio Mesa Array, Disappointment Creek Array and Wines Diversion are also shown.

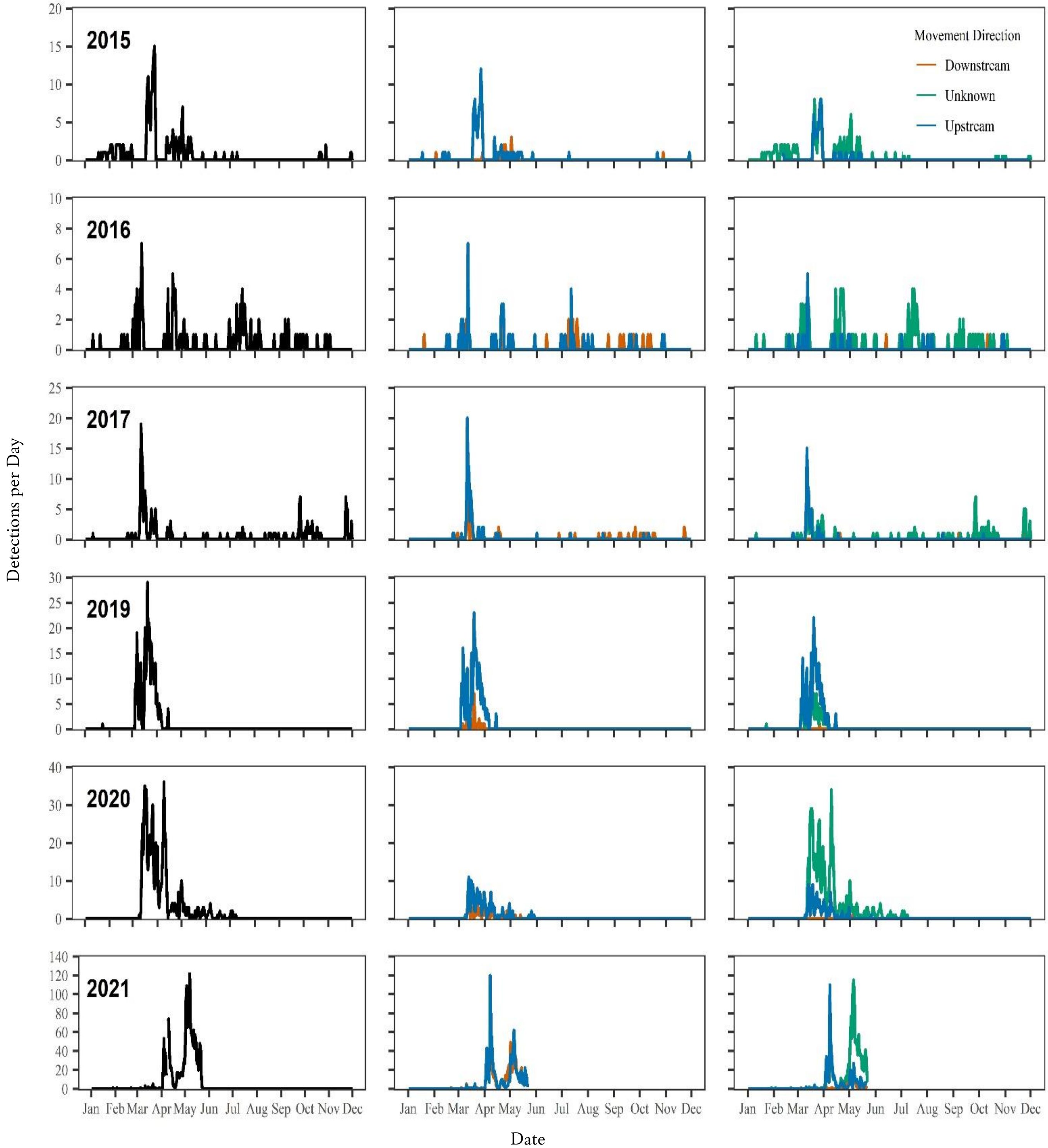

FIGURE 5. Unique daily detections of PIT-tagged fish at the Rio Mesa Array for all years with detection data (2015-2021, detection data was not available for 2018), characterized by total unique tags detected daily (left panel), movement direction using the PITR package (middle panel), and the custom code developed to determine movement direction (right panel). Note the differing y-axis scale for data visualization.

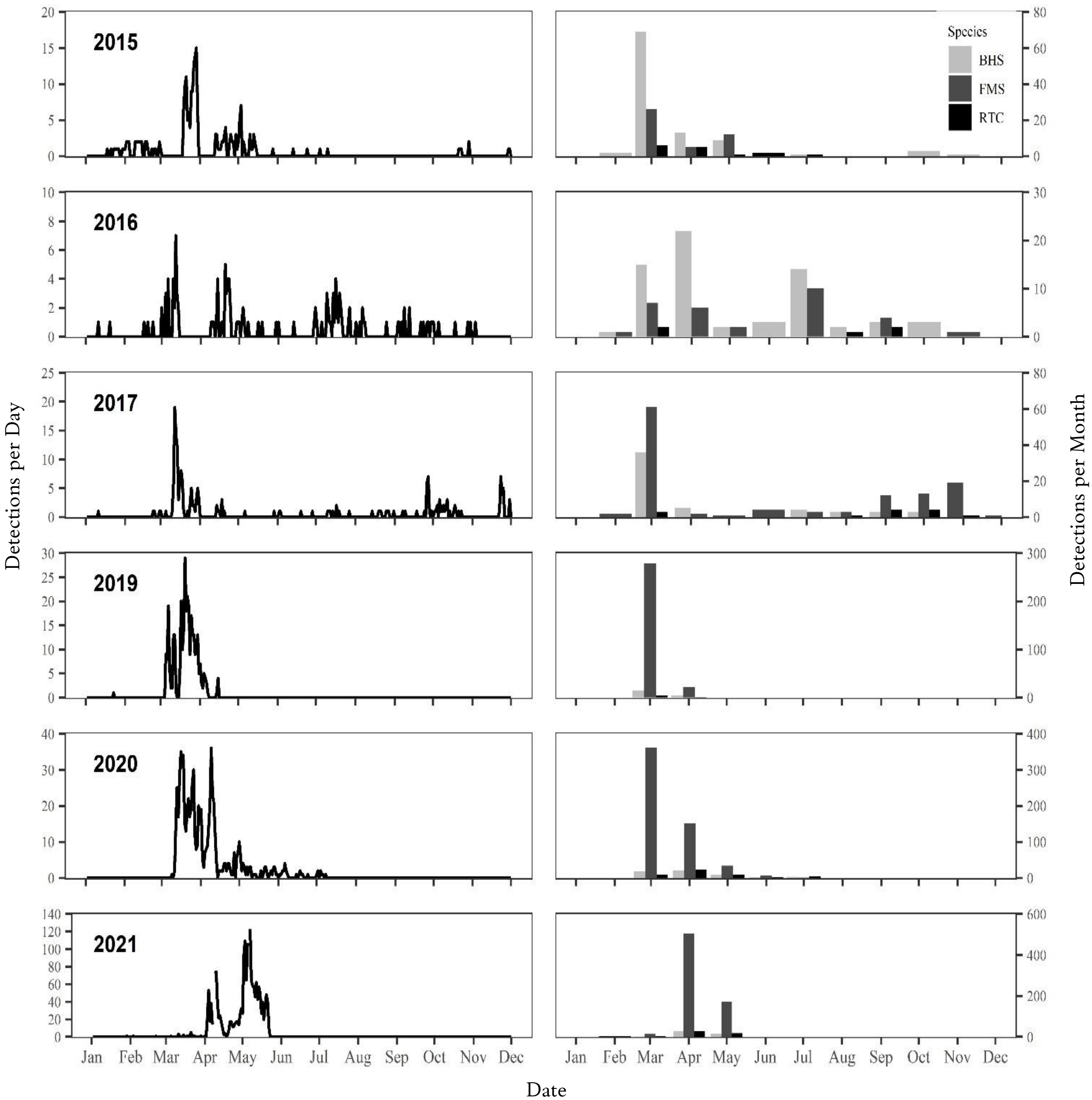

FIGURE 6. Unique detections per day (left panel) and unique number of individuals detected per month summarized by species (right panel) at the Rio Mesa Array for all years with detection data (2015-2021, detection data was not available in 2018). Note the differing y-axis scales both among years and among panels for data visualization. BHS = Bluehead Sucker; FMS = Flannelmouth Sucker; RTC = Roundtail Chub.

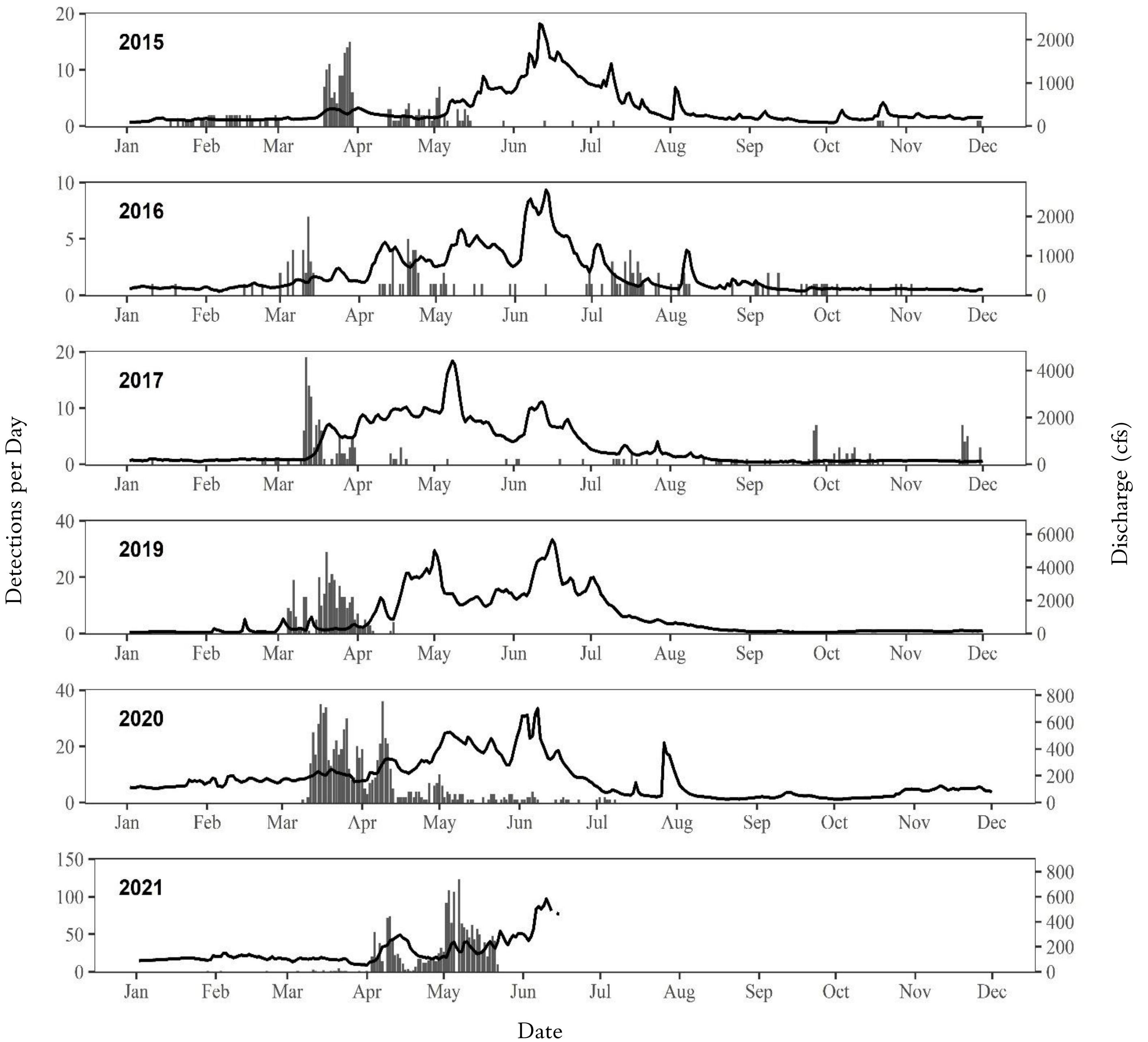

FIGURE 7. Number of unique daily detections of all PIT-tagged fish at the Rio Mesa Array and mean daily discharge (cfs) at the Cisco, Utah stream gauge (U.S. Geological Survey gauge 09180000) shown for each year of the study period (2015-2021, detection data from 2018 is not available). Note the differing y-axis scales for data visualization.

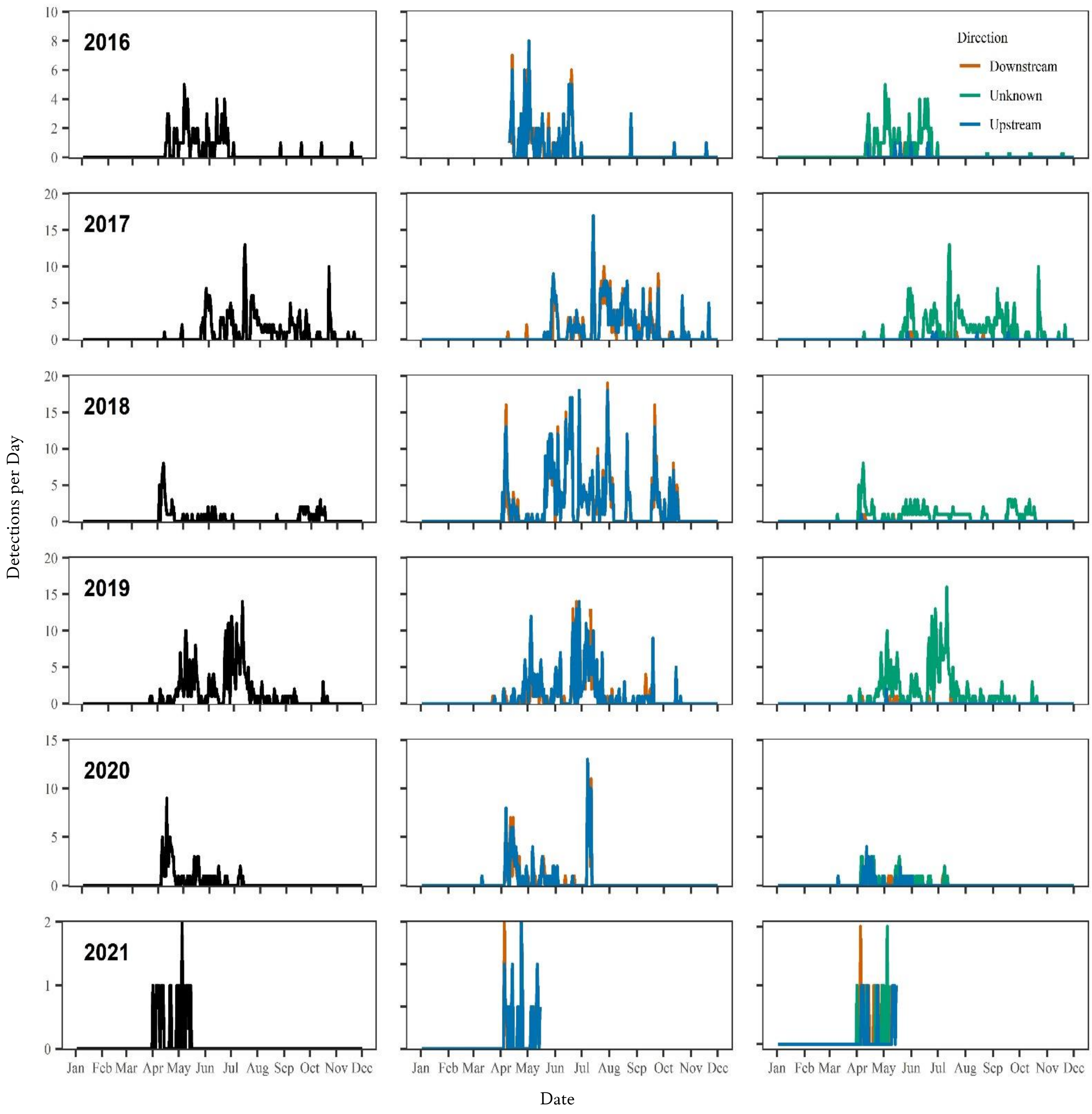

FIGURE 8. Unique daily detections of PIT-tagged fish at the Disappointment Creek Array for all years with detection data (2016-2021), characterized by total unique tags detected daily (left panel), movement direction using the PITR package (middle panel), and the custom code developed to determine movement direction (right panel). Note differing y-axis scales among years for data visualization.

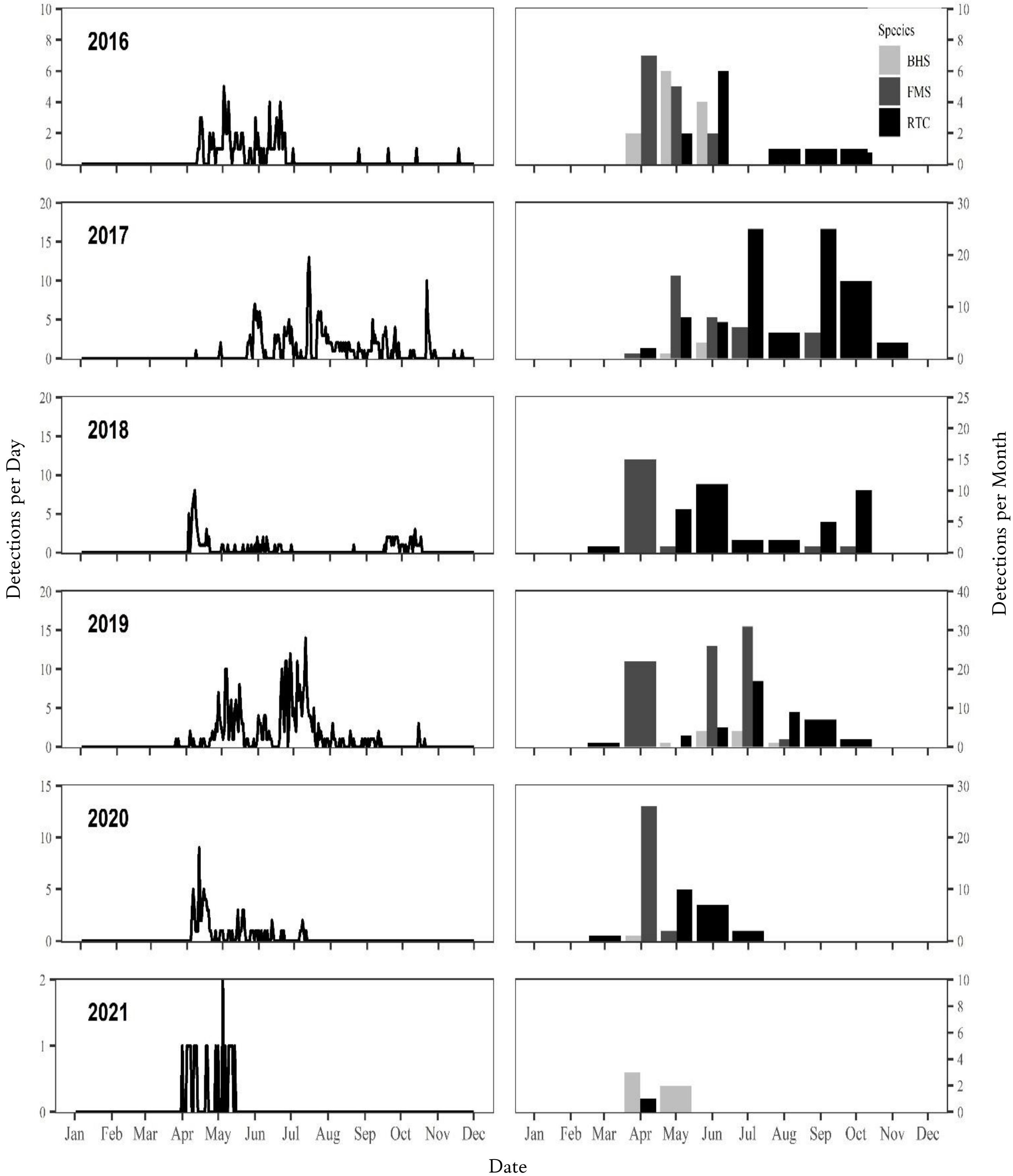

FIGURE 9. Unique detections per day (left panel) and unique number of individuals detected per month summarized by species (right panel) at the Disappointment Creek Array. Note the differing y-axis scales both among years and among panels for data visualization. BHS = Bluehead Sucker; FMS = Flannelmouth Sucker; RTC = Roundtail Chub.

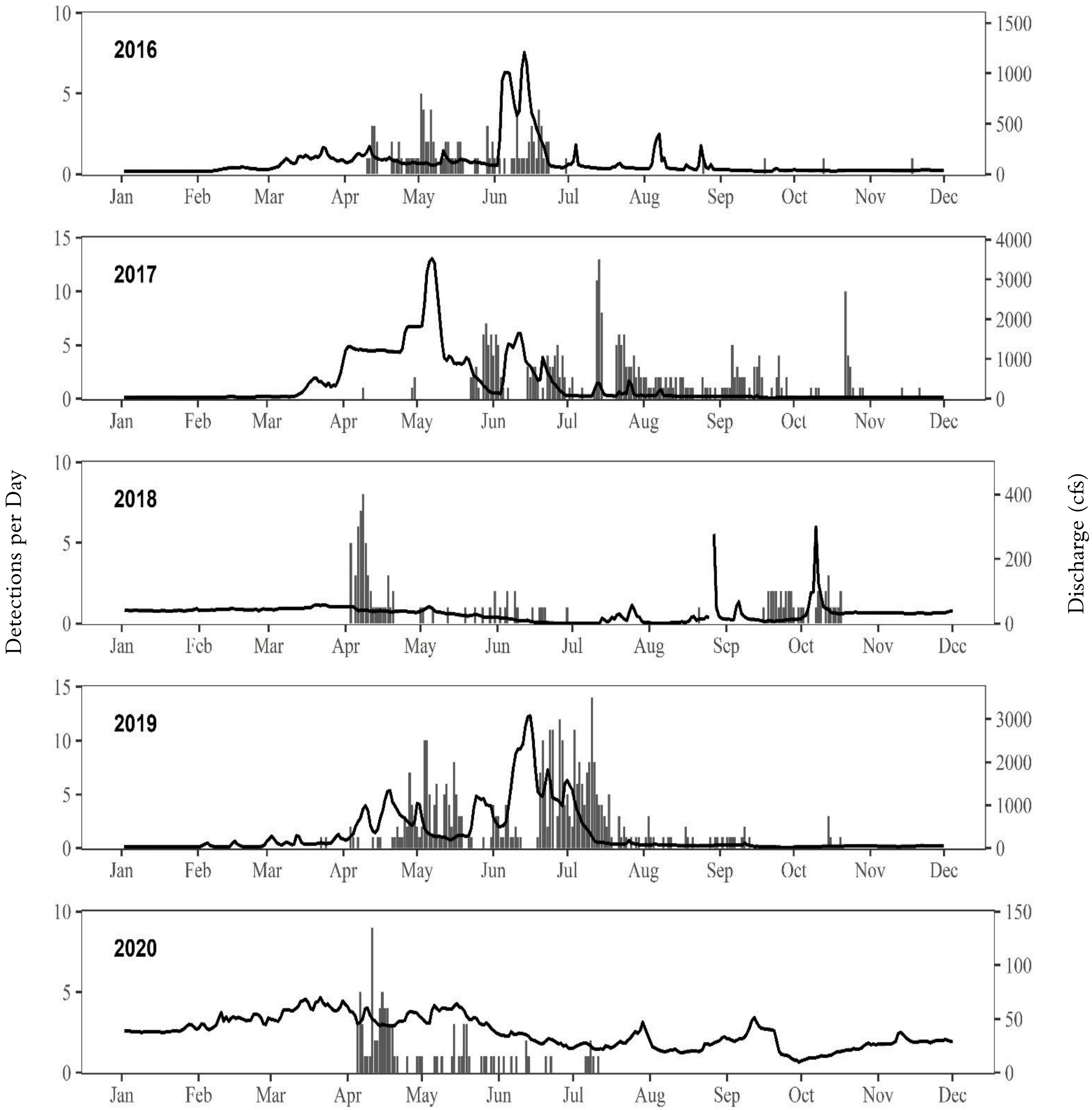

FIGURE 10. Number of unique daily detections of all PIT-tagged fish at the Disappointment Creek Array and mean daily discharge (cfs) at the Bedrock, Colorado stream gauge (U.S. Geological Survey gauge 09169500) shown for 2016-2020. Only seven fish were detected in 2021, therefore a plot is not shown. Note the differing y-axis scales for data visualization.

TABLE 1. Number of surveys in each capture water where PIT tags were deployed among years during the tagging period (2013-2021). CR = Colorado River; LD = Lower Dolores; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; SM = San Miguel River; TC = Tabeguache Creek.

	Capture Water							
Year	CR	LD	DR1	DR2	DR3	SM	TC	Total Surveys Each Year
2013	0	1	0	1	2	0	1	5
2014	0	3	0	1	3	1	2	10
2015	0	0	1	0	1	0	0	2
2016	0	0	0	0	0	0	2	2
2017	0	0	1	1	3	0	0	5
2018	1	0	0	0	1	0	0	2
2019	0	0	0	3	3	2	0	8
2020	0	0	2	0	2	1	1	6
Total Surveys Each Capture Water	1	4	4	6	15	4	6	

TABLE 2. Number of tags deployed among years and capture waters during the tagging period (2013-2020), summarized by species. CR = Colorado River; LD = Lower Dolores; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; SM = San Miguel River; TC = Tabeguache Creek.

		Capture Water							
Year	Species	**CR**	**LD**	**DR1**	**DR2**	**DR3**	**SM**	**TC**	**Total Tags Deployed Annually**
2013	BHS	0	151	0	0	6	0	29	**186**
	FMS	0	65	0	2	0	0	0	**67**
	RTC	0	7	0	4	27	0	3	**41**
2014	BHS	0	43	0	0	3	226	3	**275**
	FMS	0	29	0	0	4	138	24	**195**
	RTC	0	3	0	1	18	58	9	**89**
2015	BHS	0	0	26	0	0	0	3	**29**
	FMS	0	0	89	0	3	0	5	**97**
	RTC	0	0	4	0	9	0	2	**15**
2016	BHS	0	0	0	0	7	0	0	**7**
	FMS	0	0	0	0	2	0	0	**2**
	RTC	0	0	0	0	19	0	0	**19**
2017	BHS	0	0	0	10	4	0	3	**17**
	FMS	0	0	0	295	14	0	6	**315**
	RTC	0	0	4	187	102	0	0	**293**
2018	BHS	250	0	0	0	2	0	0	**252**
	FMS	402	0	0	0	0	0	0	**402**
	RTC	0	0	0	0	13	0	0	**13**
2019	BHS	0	0	0	14	12	34	0	**60**
	FMS	0	0	0	159	46	194	0	**399**
	RTC	0	0	0	71	29	3	0	**103**
2020	BHS	0	0	89	0	10	76	7	**182**
	FMS	0	0	322	0	0	73	4	**399**
	RTC	0	0	54	0	223	17	3	**297**
	Total Tags Deployed by Capture Water	**652**	**298**	**588**	**743**	**553**	**819**	**101**	

TABLE 3. Number tagged, number detected or not detected (n), percent of number tagged that was detected or not detected, mean total length (TL, mm) and standard error (SE) of mean total length for each species among capture waters for the Rio Mesa Array (2015-2020). Number tagged is the total number of tags deployed within the capture water within the study period, while n represents the number of individuals either detected or not detected within the study period. CR = Colorado River; LD = Lower Dolores; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; SM = San Miguel River; TC = Tabeguache Creek

	Detected at Rio Mesa Array						Not Detected at Rio Mesa Array					
Species	Capture Water	Number Tagged	n	Percent of Total	Mean TL	SE	Capture Water	Number Tagged	n	Percent of Total	Mean TL	SE
Bluehead Sucker	**CR**	250	19	8%	316	13.4	**CR**	250	231	92%	295	3.5
	LD	194	42	22%	280	7.9	**LD**	194	152	78%	278	4.8
	DR1	115	29	25%	309	7.6	**DR1**	115	86	75%	248	6.3
	DR2	24	9	38%	307	26.5	**DR2**	24	15	63%	248	19.1
	DR3	44	1	2%	395	-	**DR3**	44	43	98%	217	8.5
	SM	336	109	32%	303	4.1	**SM**	336	227	68%	264	4.8
	TC	45	3	7%	276	-	**TC**	45	42	93%	216	4.9
Flannelmouth Sucker	**CR**	402	284	71%	441	2.6	**CR**	402	118	29%	391	7.8
	LD	94	25	27%	366	23.2	**LD**	94	69	73%	260	13.4
	DR1	411	134	33%	482	3.3	**DR1**	411	227	55%	316	7.6
	DR2	454	191	42%	398	8.2	**DR2**	454	263	58%	288	7.4
	DR3	70	43	61%	418	14.0	**DR3**	70	27	39%	381	21.4
	SM	405	188	46%	437	6.4	**SM**	405	217	54%	342	7.9
	TC	39	25	64%	467	9.1	**TC**	39	14	36%	456	10.7
Roundtail Chub	**CR**	0	-	-	-	-	**CR**	0	-	-	-	-
	LD	10	5	50%	264	34.6	**LD**	10	5	50%	238	23.4
	DR1	62	19	31%	251	13.2	**DR1**	62	43	69%	230	7.2
	DR2	263	22	8%	203	8.6	**DR2**	263	241	92%	189	1.8
	DR3	440	13	3%	235	14.7	**DR3**	440	427	97%	179	1.8
	SM	78	13	17%	273	15.9	**SM**	78	65	83%	243	5.7
	TC	17	1	6%	197	-	**TC**	17	16	94%	178	8.2

TABLE 4. Number tagged, number detected or not detected (n), percent of number tagged that was detected or not detected, mean total length (TL, mm) and standard error (SE) of mean total length for each species among capture waters for the Disappointment Creek Array (2016-2020). Number tagged is the total number of tags deployed within the capture water for the study period (2013-2020), while n represents the number of individuals either detected or not detected within the study period. CR = Colorado River; LD = Lower Dolores; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; SM = San Miguel River; TC = Tabeguache Creek

	Detected at Disappointment Creek Array						Not Detected at Disappointment Creek Array					
Species	Capture Reach	Number Tagged	n	Percent of Total	Mean TL	SE	Capture Reach	Number Tagged	n	Percent of Total	Mean TL	SE
Bluehead Sucker	**CR**	250	0	-	-	-	**CR**	250	250	100%	297	3.4
	LD	194	1	1%	232	-	**LD**	194	193	99%	279	4.1
	DR1	115	1	1%	366	-	**DR1**	115	114	99%	263	5.6
	DR2	24	2	8%	236	24.5	**DR2**	24	22	92%	274	17.6
	DR3	44	5	11%	290	39.3	**DR3**	44	39	89%	212	8.4
	SM	336	6	2%	298	8.9	**SM**	336	330	98%	276	3.7
	TC	45	1	2%	-	-	**TC**	45	44	98%	218	5.0
Flannelmouth Sucker	**CR**	402	43	11%	459	4.1	**CR**	402	359	89%	423	3.4
	LD	94	2	2%	487	9.0	**LD**	94	92	98%	284	12.4
	DR1	411	5	1%	489	12.9	**DR1**	411	406	99%	369	6.5
	DR2	454	39	9%	455	7.4	**DR2**	454	415	91%	323	6.3
	DR3	70	47	67%	412	13.4	**DR3**	70	23	33%	386	24.2
	SM	405	5	1%	362	49.5	**SM**	405	400	99%	387	5.7
	TC	39	1	3%	518	-	**TC**	39	38	97%	461	6.9
Roundtail Chub	**CR**	0	-	-	-	-	**CR**	0	-	-	-	-
	LD	10	1	10%	159	-	**LD**	10	9	90%	261	19.4
	DR1	62	2	3%	267	44.5	**DR1**	62	60	97%	235	6.6
	DR2	263	31	12%	204	6.4	**DR2**	263	232	88%	189	1.9
	DR3	440	52	12%	226	5.3	**DR3**	440	388	88%	174	1.8
	SM	78	1	1%	216	-	**SM**	78	77	99%	248	5.6
	TC	17	1	6%	195	20	**TC**	17	15	88%	176	8.4

TABLE 5. Total unique PIT tags encountered each year summarized by species at the Rio Mesa Array (2014-2021, detection data not available for 2018) and Disappointment Creek Array (2016-2021). Total number of unique tags encountered each year is shown in parenthesis. BHS = Bluehead Sucker; FMS = Flannelmouth Sucker; RTC = Roundtail Chub. Other species are species other than three-species. Unknown species are encountered PIT tags that have no known associated capture information.

Rio Mesa Array			**Disappointment Creek Array**		
Year	Species Detected	Number Detected	Year	Species Detected	Number Detected
2014 (3)	BHS	1	2016 (32)	BHS	8
	FMS	1		FMS	11
	RTC	1		RTC	8
	Other Species	0		Other Species	0
	Unknown	0		Unknown	5
2015 (156)	BHS	92	2017 (95)	BHS	3
	FMS	41		FMS	28
	RTC	14		RTC	62
	Other Species	0		Other Species	0
	Unknown	9		Unknown	2
2016 (97)	BHS	52	2018 (34)	BHS	0
	FMS	27		FMS	15
	RTC	4		RTC	18
	Other Species	0		Other Species	0
	Unknown	14		Unknown	1
2017 (174)	BHS	46	2019 (138)	BHS	6
	FMS	111		FMS	94
	RTC	10		RTC	22
	Other Species	0		Other Species	0
	Unknown	7		Unknown	16
2019 (330)	BHS	19	2020 (46)	BHS	1
	FMS	302		FMS	26
	RTC	6		RTC	14
	Other Species	0		Other Species	0
	Unknown	5		Unknown	5
2020 (677)	BHS	44	2021 (7)	BHS	5
	FMS	529		FMS	0
	RTC	49		RTC	1
	Other Species	10		Other Species	0
	Unknown	54		Unknown	1
2021 (1145)	BHS	40			
	FMS	515			
	RTC	52			
	Other Species	9			
	Unknown	808			

TABLE 6. Number of unique individuals detected at the Rio Mesa Array (2015-2021) and Disappointment Creek Array (2016-2021) and the number of individuals that were detected coming from each capture water. Percent of the total is shown in parenthesis. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

Total Detected	Capture Water						
	CR	DR1	DR2	DR3	LD	SM	TAB
				Rio Mesa Array			
1,175	303 (26)	182 (15)	222 (19)	57 (5)	72 (6)	310 (26)	29 (2)
				Disappointment Creek Array			
247	43 (17)	8 (3)	72 (29)	104 (42)	4 (2)	12 (5)	4 (2)

TABLE 7. The number of each species tagged each year that were encountered at the Rio Mesa Array during the study period (2014-2021, detection data were not available for 2018). Numbers in parenthesis represent the percentage of the fish tagged (tagging year) that were detected (detection year). BHS = Bluehead Sucker; FMS = Flannelmouth Sucker; RTC = Roundtail Chub.

			Detection Year						
Tagging Year	Species	Total Tagged	**2014**	**2015**	**2016**	**2017**	**2019**	**2020**	**2021**
2013	BHS	186	0	17 (9)	10 (5)	9 (5)	1 (1)	0	0
	FMS	67	1 (1)	7 (4)	3 (4)	8 (12)	7 (10)	7 (10)	4 (6)
	RTC	41	0	2 (1)	0	0	1 (2)	1 (2)	2 (5)
2014	BHS	275	1 (1)	75 (40)	37 (13)	31 (11)	7 (3)	3 (3)	1 (1)
	FMS	195	0	24 (13)	11 (6)	32 (16)	25 (13)	17 (9)	13 (7)
	RTC	89	1 (1)	9 (5)	2 (2)	3 (3)	2 (2)	2 (2)	2 (2)
2015	BHS	29		0	5 (17)	5 (17)	1 (3)	0	0
	FMS	97		9 (5)	11 (11)	30 (31)	17 (18)	9 (10)	10 (10)
	RTC	15		0	2 (13)	0	0	0	0
2016	BHS	7			0	0	0	0	0
	FMS	2			0	1 (50)	0	0	1 (50)
	RTC	19			0	0	0	0	0
2017	BHS	17				1 (6)	0	1 (6)	0
	FMS	315				39 (12)	59 (19)	56 (18)	46 (15)
	RTC	293				7 (2)	3 (1)	12 (4)	6 (2)
2018	BHS	252					10 (4)	12 (5)	7 (3)
	FMS	402					189 (47)	184 (46)	161 (40)
	RTC	13					0	0	0
2019	BHS	60					0	23 (38)	9 (15)
	FMS	399					1 (1)	239 (60)	165 (41)
	RTC	103					0	9 (9)	6 (6)
2020	BHS	182						5 (3)	23 (13)
	FMS	399						12 (3)	113 (28)
	RTC	297						4 (1)	21 (7)
2021	BHS	129							26 (20)
	FMS	56							25 (45)
	RTC	41							0

TABLE 8. The number of each species tagged each year that were encountered at the Disappointment Creek Array (2016-2021). Numbers in parenthesis represent the percentage of the fish tagged (tagging year) that were detected (detection year). BHS = Bluehead Sucker; FMS = Flannelmouth Sucker; RTC = Roundtail Chub.

			Detection Year					
Tagging Year	Species	Total Tagged	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
2013	BHS	186	0	1 (1)	0	0	0	0
	FMS	67	1 (1)	0	0	1 (1)	0	0
	RTC	41	1 (2)	3 (7)	0	0	0	0
2014	BHS	275	6 (2)	1 (1)	0	0	0	0
	FMS	195	3 (2)	3 (2)	2 (1)	3 (2)	1 (1)	0
	RTC	89	5 (6)	1 (1)	0	0	0	0
2015	BHS	29	2 (7)	0	0	0	0	0
	FMS	97	6 (6)	1 (1)	0	0	1 (1)	0
	RTC	15	2 (13)	1 (7)	0	0	0	0
2016	BHS	7	0	0	0	0	0	0
	FMS	2	0	0	0	0	0	0
	RTC	19	0	0	0	0	0	0
2017	BHS	17		1 (6)	0	1 (6)	0	0
	FMS	315		23 (7)	13 (4)	19 (6)	3 (1)	0
	RTC	293		57 (19)	18 (6)	16 (5)	9 (3)	1 (1)
2018	BHS	252			0	0	0	0
	FMS	402			0	41 (10)	6 (1)	0
	RTC	13			0	0	0	0
2019	BHS	60				5 (8)	1 (2)	1 (1)
	FMS	399				31 (8)	15 (4)	0
	RTC	103				6 (6)	3 (3)	0
2020	BHS	182					0	0
	FMS	399					0	0
	RTC	103					2 (1)	0
2021	BHS	129						0
	FMS	56						0
	RTC	41						0

TABLE 9. Number of unique annual detections on the Rio Mesa Array (RM), Disappointment Creek Array (DC) and number of individuals detected on both PIA within the same year. (t) refers to the mean time (days) it took to travel between the two PIA. Positive values indicate that the individuals were first encountered on the RM and then the DC, while negative values indicate that the individuals were first encountered on the DC and then the RM. Only showing years with detection data at both PIA locations.

2016				2017				2019				2020			
RM	DC	Both	(t)	RM	DC	Both	(t)	RM	DC	Both	(t)	RM	DC	Both	(t)
Bluehead Sucker															
52	8	1	53	46	3	2	65	19	6	0	-	44	1	0	-
Flannelmouth Sucker															
27	11	1	48	111	28	6	83	302	94	61	52	529	26	23	28
Roundtail Chub															
4	8	0	-	10	62	4	-105	6	22	1	107	49	14	8	51

TABLE 10. Total number of three-species within the CPW PIT-tag database that were detected throughout all study years and the number of consecutive years the detected fishes were detected on each PIA. BHS = Bluehead Sucker; FMS = Flannelmouth Sucker; RTC = Roundtail Chub.

Rio Mesa Array						Disappointment Creek Array					
		Consecutive Years Detected						Consecutive Years Detected			
Species	Total Detected	2	3	4	5	Species	Total Detected	2	3	4	5
BHS	212	52	6	0	0	BHS	16	2	0	0	0
FMS	890	287	116	2	1	FMS	142	17	3	0	0
RTC	73	12	4	0	0	RTC	89	8	7	4	0

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CHAPTER II

FLANNELMOUTH SUCKER, BLUEHEAD SUCKER AND ROUNDTAIL CHUB USE OF TRIBUTARIES

Introduction

Tributaries are essential components of riverine ecosystems for many different aquatic taxa as well as for maintenance of biologic and geomorphic processes (Marteau et al. 2017; Milner et al. 2019; Vasconcelos et al. 2021). As flow alterations associated with water development projects have become ubiquitous on main-stem rivers, the importance of small tributaries for maintaining and enhancing the diversity of aquatic organisms in river networks has been illuminated (Poff and Zimmerman 2010; Pracheil et al. 2013; Vasconcelos et al. 2021). Migratory fish are aquatic organisms for which tributaries are particularly important (Pracheil et al. 2013; Bottcher et al. 2013; Spurgeon et al. 2018; Vasconcelos et al. 2021). Fish benefit from a large suite of characteristics that tributaries offer, including access to heterogeneous habitats that facilitate completion of life history stages, refuge from predators and adverse environmental conditions present in main-stem habitats, and variable temperature and hydrologic regimes that may not be accessible in main-stem habitats (Pracheil et al. 2013; Spurgeon et al. 2018; Cathcart et al. 2015). Given the critical ecological role that tributaries have for many fish species within highly altered riverine ecosystems, gathering information on the occupancy of tributaries and movements of endangered or sensitive fish species to small tributaries carries substantial conservation and management implications (Fausch et al. 2002, Laub et al. 2018).

Flannelmouth Sucker (*Catostomus latipinnis*), Bluehead Sucker (*Catostomus discobolus*) and Roundtail Chub (*Gila robusta*) (hereafter, three-species) are fishes native to the Colorado

River basin that extensively access smaller tributary streams for spawning and rearing habitat as well as refuge (Bezzerides and Bestgen 2002; Fraser et al. 2017; Laub et al. 2018). Three-species have been extirpated from approximately half of their historic range, although they remain more widespread than many other desert fish species endemic to the western United States (Bezzerides and Bestgen 2002, Hoagstrom et al. 2021). These declines are attributed to the introduction of nonnative species in addition to loss of habitat and disruption of life history processes due to flow alterations stemming from water development projects that are common throughout the Colorado River basin (Bezzerides and Bestgen 2002; Fausch et al. 2002; Laub and Budy 2015). These severe declines prompted an interstate conservation agreement that aims to reduce the likelihood that three-species will be listed under the Endangered Species Act by implementing localized conservation measures throughout the waters that three-species currently occupy (Three Species Conservation Agreement and Strategy: Utah Department of Natural Resources 2006).

Three-species use of smaller tributaries in the upper Colorado River basin is well documented (Compton et al. 2008; Cathcart et al. 2015; Fraser et al. 2017; Hooley-Underwood et al. 2019) and the ability of these species to use smaller tributaries has contributed to the persistence of the assemblage (Bezzerides and Bestgen 2002). Despite the aforementioned studies documenting three-species use and movements into upper Colorado River tributaries, such information is lacking in some of the waters that they occupy.

The Dolores River basin, a sub-basin of the upper Colorado River drainage, is of high conservation priority for three-species, as it is broadly co-inhabited by the native fish assemblage and considered one of the last remaining strongholds for three-species (Bestgen et al. 2011, Laub et al. 2018). Even though there have been several studies that have described the distribution and abundances of three-species within the Dolores River basin, these studies have largely focused on the main-stem rivers within the basin (Holden and Stalnaker 1975; Valdez et al. 1982, 1992; Bestgen et al. 2011). State and federal agencies tasked with managing the native fishery in the Dolores River basin have sampled many of the ephemeral and intermittent tributaries on several different occasions (Thompson and Hooley-Underwood 2019), yet no surveys or studies have explicitly aimed to identify the timing and magnitude of use or relate tributary use and catchment-scale movement patterns. Because of the limited information regarding three-species tributary use and associations to large-scale movement patterns within the Dolores River basin, passive integrated technology was utilized to catalog the occupancy and movements of three-species in various tributary streams throughout the drainage. Further, large-scale movement patterns and connectivity were evaluated by investigating links among detection histories of individuals implanted with Passive Integrated Transponder (PIT) tags at disparate detection points located throughout the basin. Our study was the first to use passive integrated technology to investigate tributary use and large-scale movement patterns of three-species within the Dolores River basin.

Methods

Study Area

The Dolores River basin is located in southwestern Colorado and eastern Utah (Figure 1). The catchment is drained by two main-stem rivers, the Dolores and San Miguel rivers. The Dolores River originates on the western slope of the San Juan Mountains and is approximately 250 miles long from the headwaters to the confluence with the Colorado River. Approximately 45 miles downstream from the headwaters, the Dolores River flows into McPhee Reservoir, the only major impoundment on the entire length of the river. Below McPhee Reservoir, the Dolores

River flows unimpeded for 200 river miles, although inter-basin water transfers out of McPhee Reservoir leave the Dolores River nearly dry above the confluence with the San Miguel River during drought years.

The headwaters of the San Miguel River are located in the San Juan Mountains near Telluride, Colorado. The San Miguel River flows for approximately 83 river miles before joining the Dolores River 6 miles downstream of Uravan, Colorado. The San Miguel River is unique in that the natural flow regime is largely still intact due to the absence of major dams, yet there are several diversion points that divert water for agricultural purposes.

Both the Dolores and San Miguel rivers are snowmelt driven and flow through a wide range of biotic communities including montane forests, broad alluvial grasslands, and deep remote sandstone canyons (Pontius 1997). Many of the tributaries that feed the Dolores and San Miguel rivers are characterized as intermittent or ephemeral and only provide flows to the main-stem rivers from spring through the late summer (Dolores River Dialogue 2005).

The majority of lands within the Dolores River basin are federally owned and managed by the Bureau of Land Management (BLM). Over 50% of the river miles of the Dolores River and 39% of the river miles of the San Miguel River are managed by the BLM. Overall, 48% of the perennial river miles within the drainage are managed by the BLM (R. Japuntich, BLM, personal communication). Managing such a large percentage of the perennial river miles within the Dolores River drainage means that land management decisions and conservations actions initiated by the BLM are highly impactful to the rivers and sensitive native species within it, as rivers are highly affected by the landscapes through which they flow (Fausch et al. 2002; Wiens 2002).

Fish Capture and Tagging

As part of a larger movement study aimed at investigating the basin-wide movement patterns of three-species, Colorado Parks and Wildlife (CPW), BLM and Utah Division of Wildlife Resources (UDWR) opportunistically deployed PIT tags in three-species during sampling surveys in the Dolores River basin and in a reach of the Colorado River near the confluence with the Dolores River (Figure 1). Tagging efforts within the Dolores River basin began in 2013 and PIT tags were deployed into captured three-species individuals that were ≥ 150 mm total length during all surveys. Many different capture methods were employed depending on the survey location and objectives, including backpack electrofishing, raft electrofishing, barge electrofishing, seining, gill netting and hook-and-line sampling. Captured three-species individuals were weighed (g), measured (total length; mm), and checked for signs of sexual maturity (tubercles, milt or eggs). Individuals ≥ 150 mm were scanned with a portable handheld PIT-tag reader to check for preexisting PIT tags, and untagged individuals were implanted with a 12.1 x 2.1 mm, 134.2 kHz full-duplex PIT tag (Biomark, Boise, Idaho). All tags were inserted into the body cavity ventrally, and posterior to the left pelvic fin. These tagging procedures are documented to produce high tag retention rates and minimal tag-induced mortality for three-species (Hooley-Underwood et al. 2017). Quantitative data collected on tagged fish were recorded along with the location of capture. Newly tagged fish were immediately returned to the water alive after processing was complete.

Fish Monitoring

For the tributary monitoring component of this chapter, 0.9-meter (m) submersible PIT readers (SPRs; Biomark, Boise, Idaho) were deployed in selected tributaries throughout the basin (Figure 1). Tributaries were selected based on sampling records that documented the occurrence of at least one of the three-species during previous sampling surveys. Additionally, tributaries characterized as intermittent were selected and ephemeral streams were excluded. The SPRs were deployed from April-June in 2020 and 2021, months that typically coincide with the spawning season of three-species (Bezzerides and Bestgen 2002). Each SPR was placed in a location that maximized the chances of tagged fish being detected. Therefore, points within each tributary were located where stream characteristics (e.g., channel width, channel depth) would most likely cause passing fish to travel in close proximity to the SPR. The maximum distance a SPR was placed in a tributary upstream from the main-stem river was 350-m (Naturita Creek), while the minimum distance was 40-m (Blue Creek). The SPRs were weighted down using concrete weights and anchored to the streambed using Duckbill Earth Anchors and cables (Earth Anchor, Model 88, Woonsocket, Rhode Island).

The SPRs were powered by lithium battery packs that allowed approximately 21 days of operation. Batteries were changed every 14 days to ensure continuity of data throughout the duration of the study. Each time a battery was replaced, detection data were downloaded using Biomark Tag Manager software (Biomark, Boise, Idaho). Detection data consisted of the date, time, and unique PIT-tag identifier recorded each time a tagged fish passed over and was detected by the reader.

In 2020, eight 0.9-m diameter SPRs were deployed in selected tributaries throughout the basin. The tributaries monitored in 2020 were West Creek, Blue Creek, Roc Creek, Mesa Creek, Tabeguache Creek, Naturita Creek, La Sal Creek and Horsefly Creek (Figure 1).

In 2021, tributary monitoring methods were modified because of logistical constraints and the addition of three SPRs acquired by CPW. La Sal Creek proved to be logistically complicated to monitor and few fish were detected in 2020, therefore the tributary was not monitored in 2021. Mesa Creek never flowed to the confluence with the Dolores River in 2021, so the tributary was excluded from monitoring efforts to avoid placing a SPR in a dry streambed. The private landowner that allowed access to Naturita Creek in 2020 was unwilling to allow continued access, thus it was also excluded from monitoring in 2021. Not monitoring these creeks in the second year of the study allowed deployment of those SPRs elsewhere in 2021. One 0.9-m SPR was used to monitor a different tributary, Cottonwood Creek. Additional SPRs were used to pair two 0.9-m SPRs side-by-side in West Creek and Horsefly Creek to cover more of the stream channel. Paired SPRs were treated as a single unit, thus detections on each unit within a pair were pooled. The newly acquired CPW SPRs were the 1.5-m diameter model (Biomark, Boise, Idaho). Tabeguache Creek was one of the largest tributaries that was monitored, therefore a 1.5-m SPR was deployed in the creek in 2021 in the hopes of covering more of the stream channel and increasing detection probability.

To assess large-scale movement patterns, detection data collected on a passive interrogation array (PIA) in the lower Dolores River was analyzed. Similar to the SPRs, PIA detection data consisted of a date, time and unique PIT-tag identifier that was recorded each time a tagged fish swam over and was detected by antennae. The PIA used for this analysis is known as the Rio Mesa Array (RMA) and is located approximately 11.5 miles upstream from the Dolores-Colorado River confluence (Figure 1). In 2021, to strengthen the large-scale movement pattern analysis, two detection points were added by deploying two 1.5-m diameter SPRs (Figure 1). One SPR was deployed in the San Miguel River approximately 1 mile upstream from the confluence of the San Miguel and Dolores rivers. The SPR was deployed in a narrow point in the river channel in a large pool that would increase the chances of tagged fish encounters. The second SPR was deployed in the Dolores River at the Wines Diversion structure, approximately

27.5 miles upstream from the confluence of the Dolores River and Colorado River. The Wines Diversion structure is a rock push-up dam that was constructed in 1900. Degradation in the structure resulted in a small channel that appeared to facilitate fish passage at low flows, however no formal analysis of fish passage has ever been completed at the structure for any species (Wright Water Engineers, 2017). A 1.5-m SPR was placed directly in the apparent fish passage channel at the Wines Diversion structure. Both the San Miguel River SPR and Wines Diversion SPR were anchored to the streambed using five concrete weights and attached into the nearby rocks using bolts, anchors and metal cables.

Data handling and analysis

Stored detection data on the RMA from 2020 and 2021 were accessed using the BioLogic Site Module, a website which allows users to view and download detection data from equipped PIAs in near-real time. Detection data from the tributary and main-stem SPRs were downloaded directly from the internal memory. Stored detection data on PIAs and SPRs do not include any of the capture information (e.g. species, capture water, tagging date) associated with detected individuals, therefore tag detections were merged with the CPW PIT-tag database. The CPW PIT-tag database is a repository of all known PIT tags deployed in, or near, the Dolores River basin and the associated capture information. Detected PIT tags that were not found in the CPW PIT-tag database were searched using the Species, Tagging, Research and Monitoring System (STReaMS) website (Colorado Natural Heritage Program 2018). STReaMS is a centralized, interagency PIT-tag database, maintained by the Colorado Natural Heritage Program, which acts as a repository of PIT-tag data in the upper Colorado River basin. Detected tags that had no records in the CPW PIT-tag database or the STReaMS database are referred to as unknown tags.

To document occupancy and investigate the timing of use of each tributary, the total number of unique individuals detected per day were summarized at each of the SPRs. For SPR locations that received detections in both years of the study, the number of unique tags detected per day for each year independently were plotted to document variability in detection timing and magnitude between years. The number of unique tags detected per day for the Wines Diversion and San Miguel SPRs were also plotted.

The total number of unique PIT tags detected, the number implanted in each of the three species, and the number of detected tags that could not be identified from both tributary and main-stem SPRs were summarized. To document where detected fish were tagged, the total number of individuals that were detected from each capture water for each species was summarized. Further, indications of site fidelity were investigated by identifying individuals that were encountered in both 2020 and 2021 at SPR locations that detected tagged fish during both years of the study.

For the large-scale use and movement pattern analysis, detection records of tributary and main-stem SPRs and detection records at the RMA were combined to identify individuals that were encountered among detection locations within the same year. The number of individuals that were detected at both primary (tributary SPRs) and secondary (RMA and Wines SPR) detection points within the same year were summarized for each species. In addition, the average number of days it took for each species to travel between detection points was calculated. Collectively, these analyses allowed for the evaluation of large-scale movement patterns, tributary usage, and fish passage at the Wines Diversion structure.

Results

Within the Dolores River basin, a total of 3,101 tags were deployed in three-species (Flannelmouth Sucker = 1,473 tags, Bluehead Sucker = 758 tags, Roundtail Chub = 870 tags) with an additional 652 tags that were deployed in 2018 in the Colorado River near the confluence with the Dolores River (Flannelmouth Sucker = 402 tags, Bluehead Sucker = 250 tags), resulting in a total of 3,753 tagged fish that could potentially be detected.

In 2020, PIT tags were detected in four of the eight tributaries monitored, comprising 32 tagged three-species individuals with capture records (9 Flannelmouth Suckers, 15 Bluehead Suckers, 8 Roundtail Chub) and two unknown individuals that could not be identified in the CPW PIT-tag database or the STReaMS database. The tributaries in which detections occurred were West Creek, Mesa Creek, La Sal Creek and Tabeguache Creek (Figure 2). No PIT-tagged fish were detected in Blue Creek, Horsefly Creek, Naturita Creek or Roc Creek in 2020. The detection period ranged from April 20th to June 3rd on Tabeguache Creek, April 23rd to May 15th on West Creek, May 18th to June 25th on La Sal Creek, and one Bluehead Sucker was detected in Mesa Creek on April 10th.

In 2021, PIT-tagged individuals were detected on SPRs in West Creek and Tabeguache Creek (Figure 2). The detections represented 27 three-species individuals (15 Flannelmouth Suckers, 11 Bluehead Suckers and 1 Roundtail Chub) all of which had associated capture records. Dates of detection ranged from April 12th to May 17th on Tabeguache Creek and from May 1st to May 24th on West Creek.

Of all the tributaries monitored, PIT-tagged fish were only detected on the West Creek and Tabeguache Creek SPRs in both 2020 and 2021. Interestingly, an equal number of individuals (n = 18) were detected in 2020 and 2021 on the Tabeguache Creek SPR, although the species composition differed between years, as four more Flannelmouth Suckers and three fewer Roundtail Chub were detected in 2021 when compared to 2020. Nearly the same number of tags were encountered on the West Creek SPR in both years of the study (n = 10 in 2020, n = 9 in 2021) and only native suckers were detected in the tributary. Relatively low levels of site fidelity were observed in West Creek and Tabeguache Creek. Only 2 of the 9 fish detected in 2021 on West Creek were detected in 2020, while 1 of the 18 individuals detected in Tabeguache Creek was detected in both study years. The timing of detections was different between years on the Tabeguache Creek SPR, as detections occurred earlier and ceased earlier in 2021 when compared to 2020 (Figure 2). On the West Creek SPR, the first and the last detections occurred later in 2021 when compared to 2020 (Figure 2).

The 1.5-m SPR placed in the Wines Diversion structure documented the presence of 241 unique PIT-tagged fishes from deployment on April 12th, 2021, to retrieval on June 21st, 2021 (Table 1). Many tagged fish navigating the Wines Diversion structure were likely not detected because of the late deployment date, which can be inferred from the high number of detections on the day the SPR was deployed. Overall, 21 Bluehead Suckers, 176 Flannelmouth Suckers and 7 Roundtail Chub were detected, as well as 1 Razorback Sucker x Flannelmouth Sucker hybrid that was identified using the STReaMS database. An additional 36 tagged individuals that were detected did not have any associated capture information in the CPW PIT-tag database or in the STReaMS database. Similarly, the San Miguel 1.5-m SPR was deployed on April 12th and removed on June 21st and detected 24 unique tags (eight Flannelmouth Suckers, two Bluehead Suckers, nine Roundtail Chub and five unknown individuals) (Table 2). There were many more individuals detected on the Wines Diversion SPR (n = 241) when compared to the San Miguel

SPR (n = 24), and the timing of peak detections differed, as peak detections occurred two weeks earlier on the Wines Diversion SPR when compared to the San Miguel SPR. (Figure 3).

Comparing detection records from the SPRs deployed in the tributary and main-stem locations with the detection records on the RMA, many of the three-species detected at SPR locations were also detected at the RMA within the same year. The percentage of individuals detected at SPR locations that were also detected at the RMA within the same year was generally greater than 50, although there were some exceptions. On SPRs deployed in La Sal Creek (Table 3) and West Creek (Table 4) in 2020, 20% of the individuals detected on the SPRs were detected on the RMA, yet 8 of the 10 fish detected on the West Creek SPR were tagged upstream of the RMA in 2020. The remaining two fish were encountered at the RMA earlier in the spring. Of the 24 individuals detected on the San Miguel SPR in 2021, 14 were detected on the RMA earlier within the same year (58%) (Table 2). Nine of the 18 individuals (50%) detected on the Tabeguache Creek SPR in 2020 were also detected at the RMA in 2020 (Table 5). However, seven of the individuals detected on the Tabeguache Creek SPR in 2020 were tagged in Tabeguache Creek in the same year. Excluding these 7 individuals, 9 of the 11 individuals (81%) detected in Tabeguache Creek were also detected at the RMA earlier in the year. Similarly, 12 of the 18 individuals (67%) detected on the Tabeguache Creek SPR in 2021 were detected on the RMA earlier in the year (Table 6). Unlike 2020, 8 of the 9 individuals (88%) detected on the West Creek SPR in 2021 were detected at the RMA within the same year (Table 7). The one Bluehead Sucker that was detected in Mesa Creek in 2020 was also detected at the RMA in 2020 (Table 8). Most notably, 213 of the 241 (88%) individuals detected at the Wines Diversion SPR were also detected at the RMA (Table 1). Among all PIT-tagged fish detected on both the RMA and various SPRs, only one fish (a Bluehead Sucker detected on Tabeguache Creek) was detected on an SPR prior to its detection on the RMA.

Though the primary detection points (tributary SPRs) were at different distances from the secondary detection points (RMA and Wines Diversion SPR), typically it took the native suckers half the amount of time it took Roundtail Chub individuals to travel between primary and secondary detection points. This was most apparent when looking at the average number of days it took for each of the species to travel between the RMA and the Wines Diversion SPR because of the relatively large sample size of three-species detected (n = 204). Bluehead Suckers (n = 21) and Flannelmouth Suckers (n = 176) traveled between the two detection points in an average of 5 days (SE = 0.75) and 4 days (SE = 0.27) respectively, whereas Roundtail Chub (n = 7) took an average of 18 days (SE = 8.85).

Discussion

Only a small percentage (1%) of the total tagged three-species individuals were detected by tributary SPRs. Likewise, tagged individuals were only detected on four out of the nine tributaries where SPRs were deployed. These results were surprising, given that much larger numbers of three-species have been documented using smaller tributaries elsewhere in the upper Colorado River basin and because smaller tributaries are suggested to be important habitats for three-species in many systems (Bezzerides and Bestgen 2002; Compton et al. 2008; Cathcart et al. 2015; Fraser et al. 2017; Hooley-Underwood et al. 2019; Thompson and Hooley-Underwood 2019). The low abundances of three-species detected on tributary SPRs may be an artifact of the coarse temporal resolution of the study, uneven tag distribution, low numbers of tags deployed relative to total population numbers, or a combination of these factors. The SPRs were deployed in tributaries in 2020 when the snowpack (measured as snow water equivalent) was 70% of the average in the San Miguel drainage and 23% of the average in the upper Dolores drainage as of May 1st, while in 2021 the SPRs were deployed in tributaries when the snowpack was 55% of the average in the San Miguel drainage and 1% of the average in the upper Dolores drainage as of May 1st (United States Department of Agriculture n.d.). Perhaps much greater numbers of three-species use these tributaries in years with greater snowpack resulting in higher flows. Hooley-Underwood et al. (2019) found that Bluehead Sucker and Flannelmouth Sucker use of Cottonwood Creek (intermittent tributary to Roubideau Creek, Gunnison River basin, Colorado) was largely dependent on adequate flows, a finding that supports the above inference. Deploying SPRs into the monitored tributaries in years characterized by greater snowpack and higher flows would be useful to determine if the magnitude of use of the tributaries is dependent on flows, or perhaps other factors such as habitat quality, the presence of barriers, or land-use associations.

Some of the tributary SPRs that did not detect tagged individuals (Naturita Creek, Cottonwood Creek and Horsefly Creek) are located in the San Miguel River, many miles upstream of where tagging efforts occurred. Tagging of three-species was limited to the lower 6 miles of the San Miguel River, between the confluence of the Dolores and San Miguel rivers and the confluence of the San Miguel River and Tabeguache Creek. Sampling bias is a factor that is known to complicate fisheries assessments and movement studies (Cooke et al. 2016), therefore the lack of tagging efforts higher in the San Miguel River drainage may partially explain the lack of detections on the aforementioned San Miguel River tributaries. However, these species are known to make long-distance movements in this basin (see Chapter 1), so distance from tagging reach alone is not likely the sole explanation for the lack of detections. Regardless, increased tagging and sampling efforts are needed in the upper portions of the San Miguel River to evaluate how movement patterns and tributary use of three-species tagged in upstream reaches of the drainage compare to those of individuals tagged lower in the drainage. It is likely that many of the monitored tributaries were used by untagged individuals, as only a small portion of the total individuals of three-species populations that occupy the Dolores River basin have been tagged, as evidenced by a low physical recapture percentage (<1%). In addition, three-species have been documented in several of the study tributaries where SPRs did not detect fish (Thompson and Hooley-Underwood 2019), therefore lack of PIT-tag detections does not necessarily indicate lack of use, and these tributaries should continue to be monitored if tagging efforts continue.

Movements of three-species into tributaries for spawning are increasingly well-documented, and three-species captured in tributaries in the spring are generally reproductively mature adults (Weiss et al. 1998; Compton et al. 2008; Cathcart et al. 2015; Fraser et al. 2017; Hooley-Underwood et al. 2019; Thompson and Hooley-Underwood 2019). These reasons, coupled with the fact that the timing of movements into the tributaries corresponded with the known spawning season of three-species suggests that detected three-species individuals were accessing the tributaries to spawn. However, the low number of PIT-tagged fishes detected on tributary SPRs may indicate that the majority of three-species individuals are spawning in the main-stem rivers of the Dolores River basin. Three-species are known to express variable and diverse life-history strategies that include the ability to spawn in main-stem rivers and intermittent tributaries (Bezzerides and Bestgen 2002; Utah Department of Natural Resources 2006; Hooley-Underwood et al. 2019). However, spawning in smaller tributaries may increase successful recruitment of three-species fishes, as tributaries are often characterized by warmer, low velocity, productive waters that harbor fewer predators and provide excellent rearing conditions for larval fish (Bestgen et al. 2011; Pracheil et al. 2013; Cathcart et al. 2015; Fraser et al. 2017). In addition, Cathcart et al. (2019) found that the spawning site selection of Flannelmouth Sucker, and thus the rearing habitats experienced by larvae, impacted the growth and community interactions of larvae. This suggests that three-species spawning in the main-stem rivers of the Dolores River basin, as opposed to smaller tributaries, could be affecting recruitment of larvae and juveniles. Enhancement of spawning habitat in the monitored tributaries could increase use, as well as alleviate competition for main-stem spawning sites (Fraser et al. 2017), yet further research is needed to determine the relative importance of main-stem versus tributary spawning regarding reproductive success and recruitment of three-species.

Regardless of the low numbers of individuals detected on tributary SPRs, these data are useful for acting as baseline data from which to measure change in response to environmental variability or future management actions. The SPR deployed in Tabeguache Creek recorded the highest number of unique individuals detected compared to all other monitored tributaries in both study years. The removal of an unused water diversion from Tabeguache Creek in 2014 likely increased access to suitable spawning habitat, as low numbers of native suckers in spawning condition were found above the former diversion site shortly after the diversion was removed (Thompson and Hooley-Underwood 2019). Because there were no SPRs deployed in Tabeguache Creek prior to the removal of the diversion, comparisons of the overall numbers of three-species accessing the creek pre- and post-removal cannot be addressed with these data. However, this provides an example of how detection data collected during this study will act as baseline data that can be used to identify how three-species respond to future management actions in tributaries, such as barrier removal. An opportunity to evaluate response to barrier removal exists in Mesa Creek and West Creek. In 2020, one Bluehead Sucker tagged in the

Colorado River was detected on the Mesa Creek SPR. Native suckers were detected on the West Creek SPR in 2020 and 2021. Diversions that are complete barriers to fish movement exist in lower Mesa Creek and West Creek. Redesigning the diversions to allow for fish passage and continued monitoring of the tributaries using SPRs would allow managers to evaluate three-species response to increased connectivity within the Mesa Creek and West Creek drainages. Similar opportunities to evaluate three-species response to barrier removal exist in many of the monitored tributaries, as nearly all of them have associated water diversions that impede fish movement to some degree. Such monitoring, along with barrier removal, are practical conservation actions that adhere to the guidance and policies outlined for signatories of the Three Species Conservation Agreement (Utah Department of Natural Resources 2006).

There was little evidence of tributary spawning site fidelity, as only 3 of the 27 individuals detected on tributary SPRs in 2021 were detected in 2020 as well. Hooley-Underwood et al. (2019) and Fraser et al. (2017) found much higher fidelity rates in tributary streams, which suggests that the monitored tributaries were not highly suitable spawning habitats for three-species, although this is based on small sample sizes and limited temporal resolution. As stated previously, the study years were characterized as dry because of poor snowpack, which may have contributed to unsuitable spawning habitats in the studied tributaries. Continued monitoring during wet years may reveal higher site fidelity rates, however, low site fidelity rates during wet years would contribute evidence that many tributaries in the Dolores River basin may not contain suitable habitats for three-species reproduction and perhaps need habitat enhancement.

Investigating the detection records of individuals among multiple detection points further highlighted that each of the three-species exhibit long distance migrations from the Colorado

River to habitats located throughout the Dolores River basin, including smaller tributaries (see Chapter 1). Excluding fishes tagged upstream of the RMA prior to being detected on SPRs, 94% of individuals detected at SPR locations were initially encountered at the RMA within the same year, suggesting that long-distance migration is a movement pattern and life history trait exhibited by three-species populations in the Dolores River basin. Spawning migrations are known to be an important part of the life histories of three-species (Bezzerides and Bestgen 2002; Utah Department of Natural Resources 2006), particularly for the native suckers, and have been documented in several of the basins that they occupy (Weiss et al. 1998; Cathcart et al. 2015; Fraser et al. 2017; Hooley-Underwood et al. 2019). However, the long-distance movements of Roundtail Chub observed in this study are less well-documented. Roundtail Chub were detected moving between the RMA and La Sal Creek (70 miles), as well as between the RMA and Tabeguache Creek (55 miles). The individuals exhibiting these movements were originally tagged in reaches far from the tributary SPRs where they were detected, further highlighting that even Roundtail Chub, which are generally characterized as less mobile when compared to the native suckers (Bezzerides and Bestgen 2002), make long-distance movements in the Dolores River basin (see Chapter 1). Such movements would not be possible without the relatively unimpeded connectivity among the Colorado, Dolores and San Miguel rivers, which stresses the importance of maintaining large-scale connectivity to maintain and enhance the abundance and distribution of three-species populations. The finding that each of the three-species utilizes large spatial extents within the basin must be considered when formulating a conservation plan specific for Dolores River basin three-species populations, as conservation efforts that do not consider the scale of movement of individuals or populations may not be effective (Allen and Singh 2016).

A second finding uncovered by investigating detection records at the RMA and SPRs is the ability of all three-species to navigate the Wines Diversion structure. Because all SPRs were upstream of the RMA, any individual that was encountered on both the RMA and a SPR successfully navigated the diversion. Many individuals of each of the three-species were able to navigate the diversion. During low flows, the only feasible point in the diversion that three-species would be able to navigate is the small channel created by what appears to be gradual degradation of the structure. It is unknown how long this apparent fish passage channel has existed or whether it was intentionally created, however without it, upstream migrations would not likely be possible during many flow scenarios. This small channel in the Wines Diversion structure may have maintained the connectivity that links the Colorado River to hundreds of miles of spatiotemporally diverse habitats that three-species require for fulfilling life history stages (Bezzerides and Bestgen 2002; Bestgen et al. 2011).

There are several actions that managers can take to maintain connectivity and facilitate large-scale movements and migrations. First, the relatively unregulated flow regime of the San Miguel River must be protected. Because of water development and operations of McPhee Reservoir, flows in the Dolores River are highly modified above the confluence with the San Miguel River. Thus, flows in the lower Dolores River are largely maintained by the San Miguel River throughout much of the year (Dolores River Dialogue 2005; Bestgen et al. 2011). Flows in the lower Dolores River that are amplified by the San Miguel River improve the functional connectivity among the Colorado, Dolores and San Miguel rivers. In addition, tributaries in the lower Dolores River and San Miguel River are more reliably accessible in years of poor runoff compared to tributaries in the Dolores River upstream of the San Miguel-Dolores confluence because of the natural flow regime of the San Miguel River. These perennial connections facilitated by the natural flow regime of the San Miguel River allow three-species to make long-distance migrations and access tributaries for spawning, rearing and refuge (Bestgen et al. 2011). Because it is highly unlikely that the natural flow regime will be restored in the Dolores River because of sociopolitical factors, protecting the natural flow regime of the San Miguel River carries significant conservation value for three-species through improving functional connectivity to heterogeneous habitats, among many other benefits (Poff et al. 1997; Laub et al. 2018). Second, connectivity that enables large-scale movements can be maintained or enhanced through redesigning the Wines Diversion structure. The SPR deployed at the Wines Diversion structure detected 204 three-species individuals in less than three months. This was nearly as many individuals as were detected at the Disappointment Creek Array (Figure 1) in five years of continuous sampling. Ninety-seven percent (n = 198 of 204) of three-species individuals encountered at the Wines Diversion SPR were first detected on the RMA. These results illuminate that the lower Dolores River is a distinct migratory pathway for hundreds if not thousands of three-species individuals annually. Redesigning the Wines Diversion structure without some element of fish passage would sever connectivity to hundreds of miles of perennial and intermittent habitats and impede annual migrations of three-species. This would likely be detrimental to Dolores River basin three-species populations, as migrations are important for facilitating genetic exchange, regulating metapopulation dynamics and enabling access to habitats that allow completion of life cycles (Utah Department of Natural Resources 2006; Mueller and Fagan 2008; Compton et al. 2008; Allen and Singh 2016). Restoring and enhancing connectedness to enable migration is a conservation action outlined by the Three Species Conservation Agreement (Utah Department of Natural Resources 2006). These data have shown that incorporating a fish passage structure that allows passage for all three-species will directly affect migrations, thus this conservation action should be incorporated into the management plans of all signatories.

Detections of tagged individuals on the San Miguel River SPR indicate that the San Miguel River may also act as an important migration pathway, and that there are suitable habitats for three-species within the San Miguel River. Many of the individuals detected on the San Miguel SPR were also encountered at the RMA and Wines Diversion SPR. The magnitude of detections was greater than any of the tributary SPRs in both years of the study, yet the detections likely do not reflect the total magnitude of use of the migratory pathway. The San Miguel SPR covered less than a fourth of the width of the river channel, thus it is highly likely that many PIT-tagged fish moved past the SPR undetected. A stream wide PIA in the lower reaches of the San Miguel River would be much more effective at detecting passing tagged fish. An additional stream wide array in the Dolores River above the Dolores-San Miguel River confluence would be useful to determine the relative importance of each river regarding three-species movements and migrations.

These data not only illustrate that connectivity is important and intact, they also quantify *when* connectivity is important with increased temporal resolution. By investigating detection records among several detection points, species-specific differences in movement timing were observed. Native suckers typically moved between detection points faster than Roundtail Chub. Knowledge of the average time it took for individuals to travel between detection points increases the understanding of the spatiotemporal distributions of the three-species. Such information is useful when developing sampling plans and making predictions on where migrating three-species will be located with finer temporal resolution than is available in the literature (Allen and Singh 2016). For example, with the knowledge that native suckers are likely to arrive at the Wines Diversion 4 to 5 days after being detected at the RMA, while Roundtail Chub typically take up to 20 days, managers can modify sampling efforts to intercept specific species of migrating three-species to monitor migrations or capture individuals for tagging. In addition, this knowledge can be utilized to identify specific time periods when fish passage and connectivity is needed for each species at different locations along the migration pathway. Although the sample size of three-species detected at the Wines Diversion SPR was relatively large (n = 204), allowing for strong inferences regarding movement timing, these inferences were based on only one year of data. Replicating these methods for multiple years would be useful to determine if there are differences in movement timing depending on environmental variability.

Movements of native suckers into West Creek (located upstream of where detected fish were tagged) shortly after tagging may signify a flight response caused by handling. Fraser et al. (2017) found that high numbers of native suckers exited a spawning tributary shortly after handling. However, Hooley-Underwood et al. (2019) found no such response for native suckers in a different upper Colorado River spawning tributary. While Fraser et al. (2017) found that native suckers exited a spawning tributary, native suckers moved from the Dolores River into West Creek in this study. West Creek may have been the intended destination of detected fish regardless of handling, however the observed movements could indicate that handling altered the behavior and migration routes of individuals. These observed movements were the only instance that suggested movement behavior may have been altered due to handling. In many cases, handled individuals continued to move upstream and were detected on SPRs further upstream. Nevertheless, migrating individuals should be handled with caution, as altering the spawning movements of species of conservation concern could reduce spawning success and hinder recovery efforts.

This research has established the importance of maintaining connectivity to allow for the migrations and long-distance movements exhibited by these three-species populations, yet one of the biggest knowledge gaps remaining is the specific locations of spawning sites in this drainage system. It is unknown whether migrating three-species travel to specific spawning sites or if spawning sites are widely distributed in this basin, however ensuring that adequate spawning habitats are widely available holds significant conservation value (Utah Department of Wildlife Resources 2006). Because of severe flow alterations, suitable spawning habitats are not widely or reliably available in the Dolores River above the Dolores-San Miguel confluence (Bestgen et al. 2011). However, because of the relatively natural flow regime of the San Miguel River, suitable spawning sites are more likely to be widely dispersed in both the San Miguel River and the Dolores River below the Dolores-San Miguel confluence. Therefore, protecting the natural flow regime of the San Miguel River not only has important implications for maintaining connectivity that enables the migrations observed in this study, but also for maintaining and enhancing suitable spawning habitats throughout a large portion of the Dolores River basin. Maintaining widely available spawning habitat in the San Miguel River and lower Dolores River, as well as their associated tributaries, can also be achieved through guarding against undue sediment inputs, as each of the three-species require clean rock substrates for spawning (Bezzerides and Bestgen et al. 2002; Utah Department of Natural Resources 2006; Bestgen et al. 2011).

Although only a relatively small number of three-species individuals were detected on a limited number of SPRs, these data provide useful insights into three-species movement patterns and tributary use that can be used to assist with restoration and enhancement of the native fish assemblage. These data indicated the importance and prevalence of large-scale movements exhibited by each of the three-species, which further highlights the need for maintained connectivity both within main-stem habitats, and between main-stem and tributary habitats. Such connectivity can largely be maintained through protecting flows in the San Miguel River and enhancing flows and eliminating barriers in tributaries. Data collected on two additional main-stem SPRs accentuated the utility of added detection points for describing the dominant movement patterns of these species with increased spatial and temporal resolution. With baseline data now in place, continued monitoring of the main-stem rivers and tributaries within the basin using PIAs and SPRs will provide additional data that can be compared with baseline data to evaluate responses to management actions. Conservation plans for three-species in the Dolores River basin must consider the large spatial extents utilized by these species and focus on integrating existing detection data with future monitoring efforts to increase the understanding of movement patterns and tributary use over an expansive temporal scale.

Figures and Tables

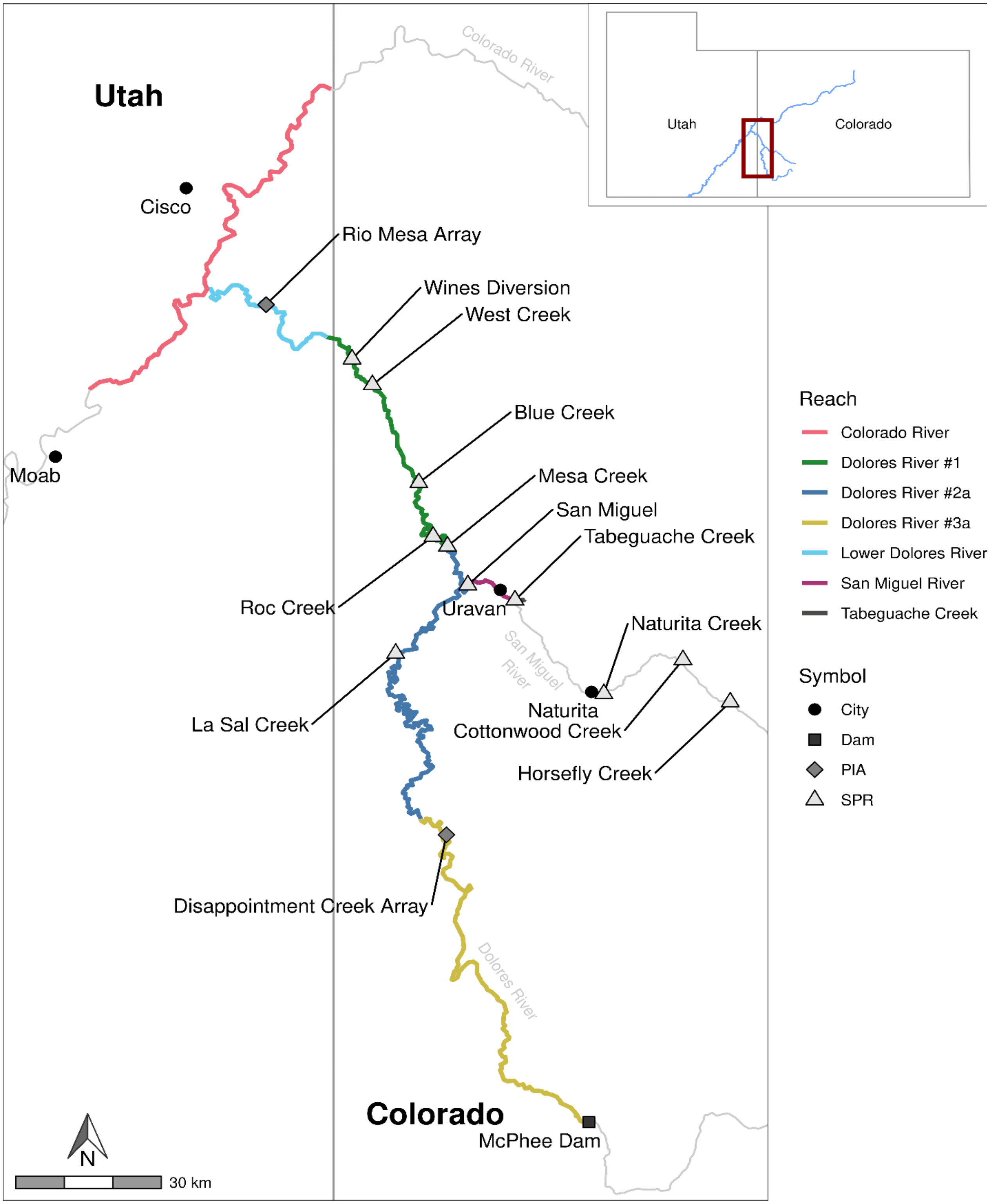

FIGURE 1. Map of the study area segmented into capture reaches. Locations of PIAs, tributary and main-stem SPRs, and McPhee Dam are shown. The Wines Diversion SPR was placed directly in a channel of the diversion structure.

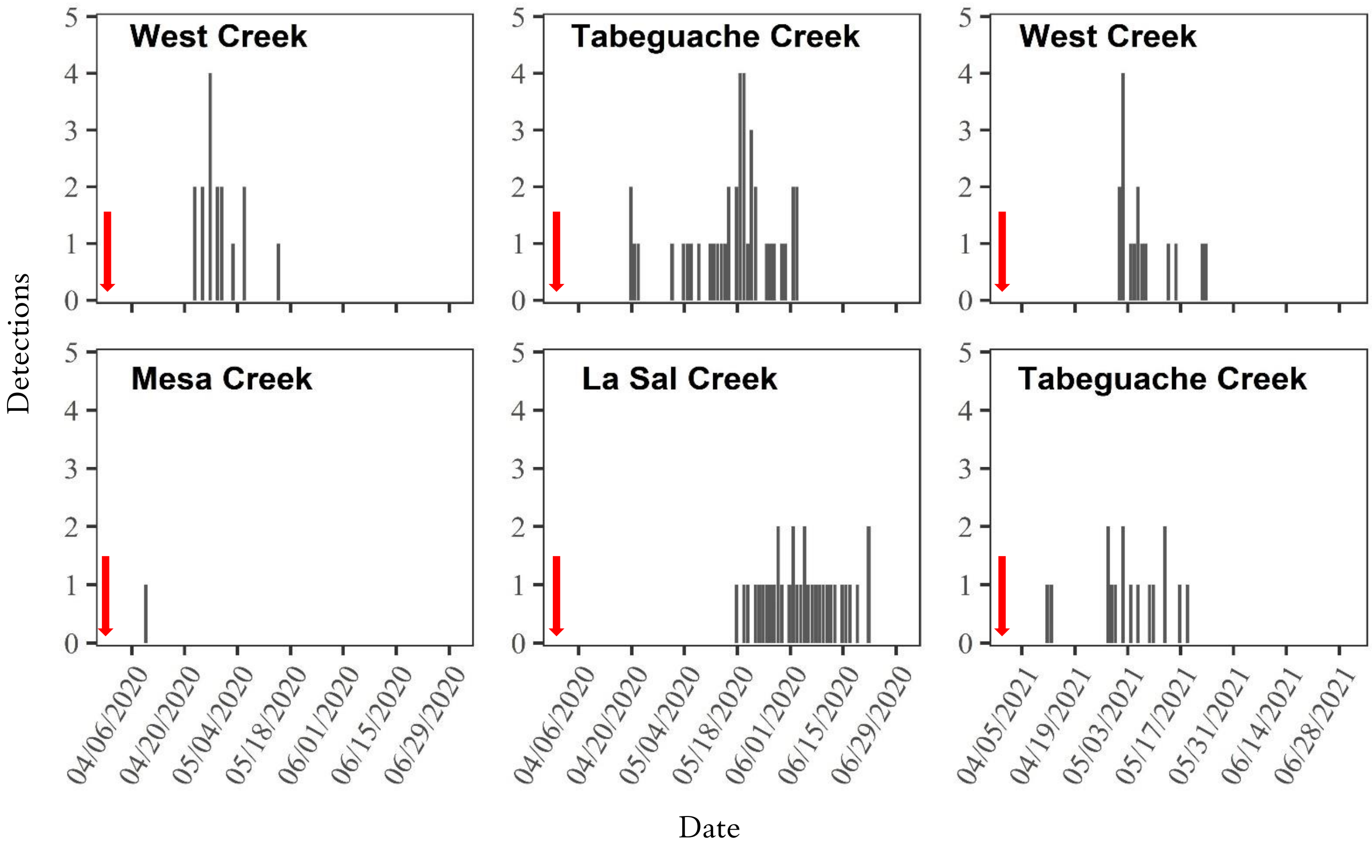

FIGURE 2. Unique daily detections of PIT-tagged fish on SPRs deployed in tributaries during the 2020 and 2021 sampling seasons. Dates on x-axis are given as month/day/year. Red arrows indicate dates of deployment.

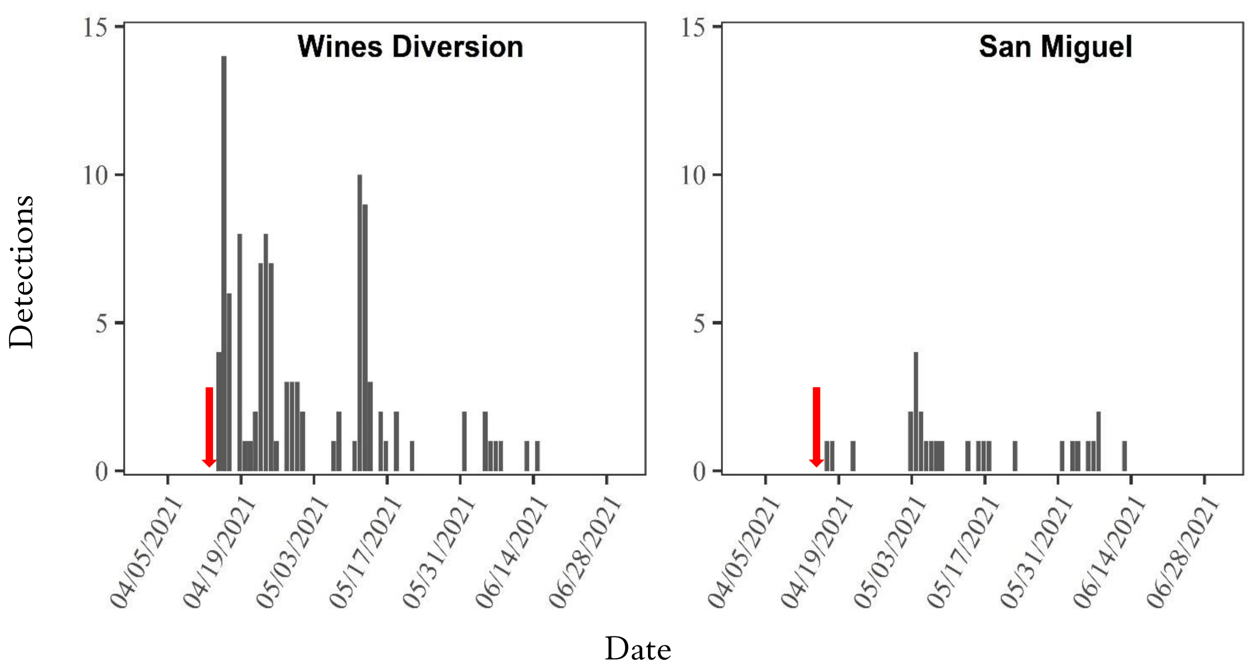

FIGURE 3. Unique daily detections of PIT-tagged fish on 1.5 m SPRs during the 2021 sampling season. Dates on x-axis are given as month/day/year. Red arrows indicate date of deployment.

TABLE 1. Detections on the Wines Diversion SPR in 2021 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA and San Miguel SPR within the same year is also shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between the detection points and the Wines Diversion SPR. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered	
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA	SM
241	BHS	21	3	13	1	0	0	4	0	17 (5)	0
	FMS	176	57	52	17	6	1	41	2	174 (4)	5 (17)
	RTC	7	0	3	0	0	1	2	1	7 (18)	1 (13)
	Other Sp.	1								1 (5)	0
	Unk.	36								14 (3)	0

TABLE 2. Detections on the San Miguel SPR in 2021 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA and the Wines Diversion SPR within the same year is also shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between each detection point and the San Miguel SPR. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered	
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA	Wines
24	BHS	2	0	0	0	0	0	2	0	0	0
	FMS	8	1	1	0	1	1	4	0	8 (18)	5 (17)
	RTC	9	1	0	1	2	0	4	1	6 (38)	1 (13)
	Unk.	5								2 (39)	

TABLE 3. Detections on the La Sal Creek SPR in 2020 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA within the same year is also shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between the RMA and the La Sal Creek SPR. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA
5	RTC	4	0	0	4	0	0	0	0	1 (55)
	Unk.	1								0

TABLE 4. Detections on the West Creek SPR in 2020 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA within the same year is also shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between the RMA and the West Creek SPR. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA
10	BHS	7	1	6	0	0	0	0	0	1 (7)
	FMS	3	0	2	0	0	0	1	0	1 (49)

TABLE 5. Detections on the Tabeguache Creek SPR in 2020 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA within the same year is also shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between the RMA and the Tabeguache Creek SPR. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA
18	BHS	7	1	0	0	0	0	2	4	3 (29)
	FMS	6	3	0	0	1	0	0	2	4 (29)
	RTC	4	0	1	0	1	0	0	1	2 (54)
	Unk.	1								0

TABLE 6. Detections on the Tabeguache Creek SPR in 2021 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA and Wines Diversion SPR within the same year is also shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between the detection points and the Tabeguache Creek SPR. Negative values indicate that the individual was detected at the Tabeguache Creek SPR prior to the RMA. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered		
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA	Wines	2020
18	BHS	7	1	1	0	0	0	5	0	1 (-4)	1 (9)	0
	FMS	10	7	0	2	0	0	1	0	10 (21)	4 (19)	1
	RTC	1	0	0	1	0	0	0	0	1 (49)	0	0

TABLE 7. Detections on the West Creek SPR in 2021 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA and the Wines Diversion SPR within the same year is also shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between the RMA and the West Creek SPR. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered		
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA	Wines	2020
9	BHS	4	0	4	0	0	0	0	0	3 (8)	1 (16)	1
	FMS	5	0	5	0	0	0	0	0	5 (16)	4 (23)	1

TABLE 8. Detections on the Mesa Creek SPR in 2020 summarized by the total number of unique detections (N), the total number of unique detections for each species (n) and the total number of unique detections for each species based on the original tagging location (Capture Water). The number of individuals detected that were encountered at the RMA within the same year are is shown. Numbers in parenthesis indicate the average number of days it took for individuals to travel between the RMA and the Mesa Creek SPR. CR = Colorado River; DR1 = Dolores River #1; DR2 = Dolores River #2A; DR3 = Dolores River #3A; LD = Lower Dolores; SM = San Miguel; TAB = Tabeguache Creek.

			Capture Water							Encountered
N	Sp.	n	CR	DR1	DR2	DR3	LD	SM	TAB	RMA
1	BHS	1	1	0	0	0	0	0	0	1 (29)

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CHAPTER 3

MONITORING TO MANAGEMENT: MANAGEMENT IMPLICATIONS DERIVED FROM PASSIVE MONITORING OF FLANNELMOUTH SUCKER, BLUEHEAD SUCKER AND ROUNDTAIL CHUB

Introduction

Approximately half of the perennial river miles within the Dolores River basin are managed by the Bureau of Land Management (BLM), which nearly doubles the amount of river miles managed by all other state and federal agencies combined. Likewise, much of the intermittent stream mileage in the basin is also under the BLM's management jurisdiction.

BLM-administered lands are partitioned into land areas that are overseen by administrative units known as field offices. Management directives for each field office are guided by a Resource Management Plan (RMP). A RMP communicates and evaluates how the BLM will execute management for each field office. The overarching goal of RMPs is to manage resources on public lands for present and future generations based on the principles of multiple use and sustained yields. The multiple use approach enables the BLM to consider and support a variety of resource uses on BLM-administered lands, with a determination to balance use based on sound science and community values. One of the uses of public lands that is sustained by RMPs that direct field offices is stewardship and conservation of resources, which includes managing habitat for native fish and wildlife species.

The land and waters of the Dolores River basin are managed by four BLM field offices. The Dolores River is overseen by the Tres Rios, Uncompahgre, Grand Junction and Moab field offices, while the San Miguel River is managed through the Uncompahgre Field Office. Habitats occupied by three-species are found within the administrative jurisdiction of each of the aforementioned field offices.

In addition to management prescriptions specific to three-species within the RMPs of each of the aforementioned field offices (BLM 2008; BLM 2015; BLM 2015: BLM 2019), the BLM also has national guidance on how to manage and conserve species designated as Sensitive Species, and this management occurs at the BLM State Office level. The BLM state director designates Sensitive Species based on the criteria found within Manual 6840 and information obtained from state wildlife agencies (U.S. Department of the Interior 2008). Manual 6840 provides guidance and establishes policy for the management of Sensitive Species. Under Manual 6840, the BLM must initiate and promote conservation actions for Sensitive Species to reduce the likelihood of future listing under the Endangered Species Act. Because three-species are designated as Sensitive Species in Colorado and Utah (the states that encompass the Dolores River basin) the BLM should place high priority on managing the public lands within the basin to accomplish three-species conservation objectives.

The BLM is also a signatory on the Three Species Conservation Agreement and Strategy (Utah Department of Natural Resources 2006). Similar to Manual 6840, the agreement also aims to minimize threats that may warrant the listing of three-species under the Endangered Species Act. As a signatory, the BLM agrees to work towards ensuring the persistence of three-species populations throughout their native ranges through developing information and directing conservation efforts that promote conservation objectives such as, establish and/or maintain connectivity between populations, develop and finalize a conservation and management strategy, and reduce or eliminate threats to three-species populations and habitats.

The designations that three-species have through mandates directed by RMPs, Manual 6840 and the Three Species Conservation Agreement and Strategy require the BLM to promote and initiate conservation actions that ensure the persistence of three-species into the future. The information gathered in this study is intended to help guide conservation efforts and management decisions for three-species on BLM-administered lands within the Dolores River basin and consequently work towards the persistence of the species throughout their native ranges.

Management Implications

This BLM-funded research adhered to the guidelines set forth by Manual 6840 and the Three Species Conservation Agreement, as well as the management guidance directed by the jurisdictional field offices of the lands within the Dolores River basin. The Tres Rios, Uncompahgre, Grand Junction and Moab field office RMP's each support the implementation of Conservation Agreements, specifically the Three Species Conservation Agreement. Therefore, the field offices are required to apply the guidance recommended by the Three Species Conservation Agreement, in addition to the guidance and policies mandated in Manual 6840 for Sensitive Species.

Both Manual 6840 and the Three Species Conservation Agreement and Strategy advocate for monitoring of three-species populations to determine life history and habitat requirements, and overall conservation needs. This research pursued monitoring of three-species through the utilization of passive integrated technology, which includes Passive Integrated Transponder (PIT) tags, Passive Interrogation Arrays (PIAs) and Submersible Portable Readers (SPRs). Passive integrated technology proved to be an effective method for monitoring three-species populations and capturing movement data. While 34% of the total PIT tagged individuals were detected on PIAs, less than 1% of the total tagged individuals were physically recaptured during sampling. Although passive integrated technology has a high overhead cost, it is an effective method for increasing recapture data on individuals, especially in systems that are difficult to monitor because of logistical issues with active sampling techniques. Given that much of the Dolores and San Miguel rivers are often logistically difficult to sample and the proven efficiency of passive integrated technology for monitoring three-species within the basin, wildlife management agencies should continue to employ the technology and invest in additional arrays and readers.

Such monitoring also provided valuable information regarding the life history requirements, habitat requirements and the overall conservation needs of the Dolores River basin three-species fishery. Large numbers of PIT tagged individuals detected on the Rio Mesa Array (RMA) in March and April each year revealed the annual spawning migrations of hundreds of native suckers as well as many Roundtail Chub into the Dolores River basin. These migrations indicate that there are suitable spawning habitats within the basin, and that migrations are life history strategies exhibited by these three-species populations. In addition, these migrations highlight the unbroken connectivity between the Dolores River and Colorado River. Further, through comparing yearly detection data on the two arrays, long-distance movements of each species that span over a hundred miles were revealed.

Each of these findings can be used to guide conservation actions. With the knowledge that portions of three-species populations make annual spawning migrations that begin as early as mid-March, migration corridors should be protected from threats that may impede movements and disrupt spawning. The Moab and Uncompahgre field office RMPs do have stipulations that prohibit in-stream channel work during the spawning period (generally April-July), however this research highlights the need for protecting the March-April migration period as well. Although the lower Dolores River represents a significant migration corridor, it is still unclear where migrating individuals travel to once inside the basin. Additional arrays and readers installed in the Dolores River, San Miguel River, and tributaries, paired with continued tagging efforts, may help to identify migration corridors and isolate critical habitats elsewhere in the basin.

Migrations from the Colorado River into the Dolores River are possible because of relatively unimpeded connectivity between the two rivers. Additionally, connectivity is relatively intact between the Dolores River and San Miguel River. Thus, preserving such connectivity is a conservation need for three-species that must be protected and enhanced whenever possible. Currently, an opportunity exists to enhance connectivity and facilitate three-species migrations by redesigning the Wines Diversion structure. The data shows that each of the three-species can navigate the diversion, however it is unknown if certain flows may inhibit passage and what the population-level effects of enhanced passage may be. A new diversion structure that allows fish passage at a wide range of flow scenarios is one way that connectivity can be enhanced. Building such a diversion structure would minimize the threat of impaired connectivity, and allow migrating three-species enhanced access to hundreds of miles of diverse habitats.

A caveat of increased connectivity and improved passage at a rebuilt Wines Diversion structure is that such a change may also increase the threat of invasion by non-native species that may compete, prey upon, or hybridize with members of the native assemblage. Especially concerning is the threat of invasion by non-native suckers, namely White Suckers, that readily hybridize with native suckers. Non-native suckers and associated hybrids are still relatively rare in the Dolores and San Miguel rivers. This attribute adds conservation value to the Dolores River basin, as many of the basins that comprise the upper Colorado River basin are heavily invaded by non-natives. The reasons for this relatively low degree of invasion of non-native suckers is still largely unknown and warrants further investigation. Minimizing and controlling threats imposed by non-native species is one of the conservation actions outlined by the Three Species Conservation Agreement and Manual 6840. Therefore, any modifications to the Wines Diversion structure should carefully consider the implications of improved connectivity for non-native species and these implications should be measured during the planning of the new structure. This research shows the high importance of connectivity for Dolores River basin three-species populations, thus a structure that enhances connectivity for native fish while concurrently excluding non-natives must be advocated. However, increasing connectivity at the Wines Diversion structure for native species and excluding non-native species may not be possible without manual sorting of fish. This is because fish passage structures are often designed to allow passage based on the physical capabilities of fishes, and there is considerable overlap in the physical capabilities of three-species and non-native fish. Therefore, a trap-and-sort fishway where upstream-bound fishes are captured and manually sorted may be the only feasible option to fulfill the dual objectives. While trap-and-sort fishways may have high operational costs, the knowledge of the timing of three-species migrations obtained through this study is useful to lower such costs. Three-species were primarily detected at the RMA moving upstream in March and April each year, therefore a trap-and-sort fishway would only need to be operated during these peak migration periods, cutting operational costs significantly.

Maintaining connectivity that facilitate migrations can also be achieved through minimizing flow depletions, especially during the spawning period. The BLM should avoid permitting uses that require flow depletions, such as mineral development that utilizes suction dredging, and oil and gas extraction operations that consume water for production. The San

Miguel River is particularly essential for maintaining connectivity. Because the Dolores River is highly regulated, maintaining the relatively unregulated flow regime of the San Miguel River is of critical importance for preserving functional connectivity. Activities or projects that deplete flows in the San Miguel River must be minimized to help sustain connectivity and enable migrations. Not only are unregulated San Miguel River flows important for connectivity, such flows are also vital for maintaining geomorphic processes that enhance three-species spawning habitats in the San Miguel River and Dolores River downstream of the San Miguel confluence. Resource agencies should collaborate to install regulatory mechanisms for the long-term protection of San Miguel River flows because of the high conservation value that the natural flow regime has for three-species migrations, connectivity, and habitats.

The importance of connectivity was further highlighted by the long-distance movements of three-species between tagging reaches and detection points. Nearly half of the native suckers tagged in two reaches that are least 55 miles away from the RMA were later detected on the array. Long-distance movements were also emphasized by individuals detected at both PIA locations. The PIAs are separated by 120-river miles and almost 60% of individuals detected on the Disappointment Creek Array (DCA) also had detection records on the RMA. Manual 6840 states that the management of Sensitive Species must be carried out at the correct spatial scales. This means that management activities must account for the large-spatial extents that three-species utilize, whether it be for migrations or dispersal. One conservation action that acknowledges that three-species movements span large-spatial extents is maintaining and enhancing connectivity. In addition to the management actions described previously that work towards improving connectivity, obtaining instream flows in tributaries throughout the basin will improve functional connectivity both in main-stems and between main-stems and tributaries.

Securing instream flows in tributaries will ensure that additional water depletions in tributaries are minimized. This water that remains in tributaries can then be delivered to the main-stems, thus maintaining functional connectivity that is crucial for movement among spatially distant habitats. Although instream flow rights are junior to senior water rights, securing instream flows at least allows wildlife agencies to comment on water issues when they arise.

Along with improving connectivity within main-stems, securing instream flows in tributaries will facilitate three-species movement into tributaries. Smaller tributaries, both perennial and intermittent, are increasingly shown to provide habitats for the spawning, rearing, and refuge of three-species. This study contributed further evidence that three-species are utilizing tributary habitats, and often move long distances to reach such habitats. Enhancing access to tributaries throughout the Dolores River basin through protecting tributary flows is a fundamental conservation action that may help to improve the overall status of the populations. A second conservation action that can be employed to enhance access and increase overall habitat availability in tributaries is the removal or redesign of instream diversions that act as barriers to movement.

Tabeguache Creek, a tributary monitored during this study, exemplifies the benefits of barrier removal in tributaries for three-species. An unused instream diversion that was a barrier to fish movement was removed from the stream in 2014. Prior to removal, the stream was sampled above the barrier and only several small three-species individuals were found. The stream was sampled again shortly after removing the diversion and many large three-species were found occupying the stream. A SPR deployed in Tabeguache Creek for this study documented large three-species individuals accessing the creek, and over 60% of the individuals detected were prior detected at the RMA within the same year. The RMA and Tabeguache Creek are separated by approximately 70 miles, accentuating the long-distance movements these species are exhibiting in the basin. The removal of the diversion in Tabeguache Creek enabled three-species access to miles of functional habitats. Similar opportunities for barrier removal or redesign exist in many of the tributaries throughout the basin. Efforts made to remove or improve passage at as many of these diversions as possible will work towards the improved status of three-species that is the ultimate goal of the guidance set forth in the Three Species Conservation Agreement and Manual 6840. Continuing to deploy SPRs in tributaries pre- and post-diversion removal and improvement is essential to evaluate the progress of employed conservation actions and should be promoted and pursued by the BLM.

A fundamental component to conservation actions that work towards the recovery and persistence of three-species populations is that they benefit from cooperative and collaborative efforts, especially in the light of the knowledge that three-species movements overlap state borders. A major obstacle encountered when managing this study was that thousands of tags detected by arrays and readers were not identifiable in the STReaMS database, the repository for all of the PIT-tag data compiled for the Upper Colorado and San Juan River Endangered Fish Recovery Programs. However, because it is the only database of its kind for upper Colorado River basin PIT tag efforts, PIT tag data for non-endangered fishes is often managed and retrieved from STReaMS as well. Many PIT tags deployed by state agencies in the Dolores River basin were never reported to STReaMS and instead were filed in separate databases or sampling records. Thus, the management, retrieval, and analysis of PIT-tag databases and detection data was complicated. For this same reason, it is believed that many of the unknown tags detected on arrays and readers are due to lack of coordination between state and federal agencies that deploy PIT tags. Although all PIT tags deployed in this study were submitted to the STReaMS database in a timely manner, a separate database was created specifically for PIT tags deployed in the Dolores River basin above the Colorado-Utah state border for ease of management and analysis. The Three Species Conservation Agreement is intended to be a collaborative effort among all signatories and Manual 6840 advises that all interested parties concerned with three-species conservation efforts cooperate for the shared goal of three-species persistence. If monitoring of three-species via passive integrated technology is continued in the upper Colorado basin, there should be a significant effort among state and federal wildlife agencies to coordinate and collaborate on PIT tagging efforts and to ensure that PIT-tag databases, such as STReaMS, are equipped and supported to compile and manage PIT tag data and detection records of non-endangered fishes.

One of the most broad and basic conservation recommendations guided by the Three Species Conservation Agreement is to establish and maintain information pertaining to three-species. This study was the first in the Dolores River basin to establish information regarding movement patterns of three-species populations. The data collected during this study are not only important for filling knowledge gaps regarding three-species life history, habitat requirements and movement needs, they also serve as baseline data for three-species movements from which to measure change. Utilizing these data, the BLM and state wildlife management agencies can compare future data collected to these data to observe how three-species movement patterns may be responding to management actions and environmental changes. Obtaining such baseline data on movement is vital to describe variations in population abundances and distributions and formulate further conservation actions. Continuing to monitor three-species movements and migrations will strengthen the deductions that can be made regarding the overall status and conservation needs of Dolores River basin three-species populations, information that is vital to minimizing threats that reduce the likelihood of these species requiring listing under the Endangered Species Act (ESA).

While it has been demonstrated that the BLM has adhered to many of the guidelines presented in the Three Species Conservation Agreement and Manual 6840 regarding gathering information to guide conservation efforts, it will be the duty of the BLM and other signatories to execute the data-based guidance given in this report. The Dolores River basin is currently a three-species stronghold, yet implementing the aforementioned conservation measures will work towards minimizing threats and maximizing habitats for the sustained conservation of the species. Recovering three-species and establishing robust and resilient populations in the Dolores River basin is critical to the multiple-use mandate on BLM-administered lands, as other land uses and values can receive more focus as these species populations recover.

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