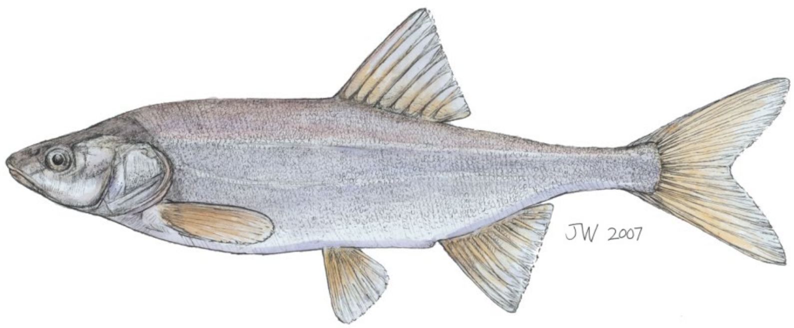
THE VIRGIN RIVER FISHES

Woundfin
(*Plagopterus argentissimus*)



Virgin River Chub
(*Gila seminuda*)

5-Year Review:
Summary and Evaluation

2020

U.S. Fish and Wildlife Service
Utah Field Office
West Valley City, Utah

5-YEAR REVIEW

Species Reviewed: woundfin (*Plagopterus argentissimus*) / Virgin River chub (*Gila seminuda*)

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1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Craig Hansen, Interior Regions 5 and 7 Endangered Species Recovery Coordinator, (303) 236-4749.

Lead Field Office: George Weekley, Utah Ecological Services Field Office, (801) 975-3330.

Cooperating Field Office(s): Brian Wooldridge, Arizona Ecological Services Field Office, (928) 556-2106; Michael Schwemm, Nevada Fish and Wildlife Office, (702) 515-5079.

1.2 Methodology used to complete the review

Section 4(c)(2)(A) of the Endangered Species Act of 1973, as amended (ESA) (16 U.S.C. 1531 et seq.) requires that we conduct a review of listed species at least once every 5 years. We then, under section 4(c)(2)(B) and the provisions of subsections (a) and (b), determine on the basis of such a review whether or not any species should be removed from the List of Endangered and Threatened Wildlife and Plants (delisted), or reclassified from endangered to threatened (downlisted), or reclassified from threatened to endangered (uplisted).

1.3 Background

1.3.1 Federal Register Notice citation announcing initiation of this review

79 Federal Register (FR) 25883, May 6, 2014 – Initiation of 5-year status reviews of nine species in the mountain-prairie region.

1.3.2 Listing history

Original Listing - woundfin
FR notice: 35 FR 16047
Date listed: October 13, 1970
Entity listed: Species
Classification: Endangered

Original Listing – Virgin River chub
FR notice: 54 FR 35305
Date listed: August 24, 1989
Entity listed: Species

Classification: Endangered

The population of Virgin River chub that resides in the Muddy River in Nevada was not included in the species' original listing (54 FR 35305, August 24, 1989). In 1995, the U.S. Fish and Wildlife Service (USFWS) proposed a status review of the population of Virgin River chub that resides in the Muddy River in Nevada, but this review was not completed (refer to section 1.3.3). Therefore, the legal status of the Muddy River population of Virgin River chub under the Endangered Species Act is unclear. We will clarify the status of this population under the Endangered Species Act before the next five-year review, and, if needed, we will amend the Virgin River Fishes Recovery Plan to include populations in the Muddy River. The most recent information on the Muddy River shows a stable population of Virgin River chub at a low level (Bio-West 2018).

1.3.3 Associated rulemakings

- 42 FR 57329, November 2, 1977 – Proposed designation of critical habitat for the woundfin.

- 44 FR 12382, March 6, 1979 – Proposed designation of critical habitat for the woundfin was withdrawn. The 1978 amendments to ESA required proposals to be withdrawn if not finalized within two years.

- 43 FR 37668, August 23, 1978 – Proposed rule to list the Virgin River chub as endangered and designate critical habitat.

- 45 FR 64853, September 30, 1980 – Proposed rule to list the Virgin River chub as endangered was withdrawn due to the 1978 amendments to ESA.

- 50 FR 30188, July 24, 1985 – Determination of experimental status for certain introduced populations of Colorado squawfish and woundfin. Applied to locations within the Gila River drainage in Arizona and Nevada.

- 51 FR 22949, June 24, 1986 – Proposal to list the Virgin River chub as endangered and designate critical habitat.

- 54 FR 35305, August 24, 1989 – Final rule to list the Virgin River chub as endangered. Designation of critical habitat was postponed to allow time for an analysis of economic and other impacts. The Muddy River population (Moapa River) was not affected by this listing of Virgin River chub.

- March 18, 1994 – The U.S. District Court of Colorado ordered us to designate critical habitat for the woundfin, Virgin River chub, and Virgin spinedace (if it is listed).

- 59 FR 25875, May 18, 1994 – Proposed rule to list the Virgin spinedace as threatened.

- 60 FR 17296, April 5, 1995 – Proposed rule to designate critical habitat for woundfin, Virgin River chub, and Virgin spinedace.

- April 11, 1995 – The USFWS and partners sign the Virgin Spinedace Conservation Agreement, which precluded the need to list this species.

- 60 FR 37866, July 24, 1995 – Proposed change (for Virgin River chub) from subspecies to vertebrate population segment in Virgin River and notice of status review of Virgin River chub in the Muddy River. We abandoned this action when Congress enacted a temporary (Fiscal Year 1995 and part of Fiscal Year 1996) moratorium on final listing actions.

- 61 FR 4401, February 6, 1996 – Withdrew the proposal to list Virgin spinedace and designate critical habitat.

- In accordance with Listing Priority Guidelines (61 FR 24722, May 16, 1996, 61 FR 64475, December 5, 1996, 63 FR 25502, May 8, 1998), the USFWS determined that designation of critical habitat was a low priority as listing actions became backlogged during the moratorium of Fiscal Year 1995 and 1996.

- August 27, 1999 – The U.S. District Court of Colorado ordered us to designate critical habitat for the woundfin and Virgin River chub by January 20, 2000.

- 65 FR 4140, January 26, 2000 – Designation of critical habitat for the woundfin and Virgin River chub. As part of this ruling, we recognized full species status for the Virgin River chub (*Gila seminuda*).

1.3.4 Review history

Cursory 5-year reviews for all listed species were initiated by our headquarters office on May 21, 1979 (44 FR 29566) and on November 6, 1991 (56 FR 56882). A species-specific review for woundfin and Virgin River chub was initiated April 7, 2006 (71 FR 17900) and completed in 2008 (USFWS).

1.3.5 Species' Recovery Priority Number at start of 5-year review

The woundfin has a Recovery Priority Number of 1C on a scale of 1 – 18 (Appendix A). This represents a species with the highest degree of threat and a high potential for recovery coupled with the rarest of taxonomic classifications (i.e., monotypic genus) (USFWS 2005a).

The Virgin River chub has a Recovery Priority Number of 2C. This represents a species with a high degree of threat and a high potential for recovery.

The "C" indicates that recovery of both species is in conflict with construction, development, and other forms of economic activity.

1.3.6 Recovery Plan

Name of plan: Virgin River Fishes Recovery Plan (Recovery Plan)
(See: http://ecos.fws.gov/docs/recovery_plan/950419a.pdf)
Date issued: 1994 (signed April 19, 1995)
Previous versions: Original Woundfin Recovery Plan (July 1979); Woundfin Recovery Plan – First Revision (March 1, 1985)

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment Policy

2.1.1 Are the species under review vertebrates? Yes

2.1.2 Are the species under review listed as a Distinct Population Segments? No

2.1.3 Is there relevant new information for these species regarding the application of the Distinct Population Segment policy? No

2.2 Recovery criteria

2.2.1 Do the species have a final, approved Recovery Plan containing objective, measurable criteria? Both species have a final, approved Recovery Plan. However, the plan needs to be revised, as it is over 20 years old and does not contain objective, measurable criteria for delisting. In addition, Virgin River chub does not have delisting criteria in the Recovery Plan. However, we are currently developing a quantitative delisting criteria for Virgin River chub that will be published in the Federal Register in 2019.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? No. The biological information in the Recovery Plan is not completely up to date and we need to reassess the criteria for delisting. However, the recommendations provided to direct recovery of Virgin River fishes are still applicable. In addition, the Recovery Plan may need to be revised when a future status review of the Muddy River population of Virgin River chub is completed (USFWS 1994).

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria? Yes. The Recovery Plan directs the USFWS, the participants of the Virgin River Resource Management and Recovery Program (VRP; see section 2.3.2.2), as well as other conservation entities to focus on ameliorating the destruction and modification of habitat and to address the negative effects of disease, competition, and predation on native fish recovery.

2.2.3 List the recovery criteria as they appear in the Recovery Plan
The primary objective of the Recovery Plan is to prevent the extinction of the woundfin and Virgin River chub and secure the long-term survival of

each of these species. Specific downlisting criteria are identified in the Recovery Plan for woundfin and Virgin River chub. These criteria do not identify quantifiable thresholds. However, we believe that the qualitative nature of these criteria is still appropriate based on current recovery efforts and achievements. In the Recovery Plan, the delisting criteria for woundfin were considered interim because the opportunity and potential locations of reestablishment of additional populations was uncertain. No delisting criteria were determined for Virgin River chub. As discussed above, we are currently developing a quantitative delisting criterion for Virgin River chub that will be published in the Federal Register in 2019.

Downlisting criteria – Virgin River Chub and Woundfin

1) Virgin River flows essential to the survival of all life stages of Virgin River chub and woundfin are ensured. This will include development and implementation of operational criteria for existing dams, reservoirs, and diversions that provide for flows sufficient to sustain all life stages near historic levels of abundance; acquisition of priority water rights to ensure instream flows of sufficient water quality and quantity from La Verkin Springs (also known as Pah Tempe Springs and Dixie Hot Springs) downstream to Lake Mead to ensure the species' survival; and agreements to ensure passage, timing, and magnitude of flows necessary for channel maintenance during appropriate periods of the year.

2) Degraded Virgin River habitats from La Verkin Springs to Lake Mead are improved and maintained to allow continued existence of all life stages at viable population levels.

3) Barriers to upstream movements of introduced fishes are established, and red shiner and other nonnative species that present a major threat to the continued existence of the native fish community are eliminated upstream of those barriers.

Interim Delisting criteria - Woundfin

1) Two additional self-sustaining woundfin populations become established in the wild within the species' historic range. This will require that adequate protection of available habitat and instream flows are maintained, the populations are self-sustaining for a minimum of 10 consecutive years, and a plan for genetic exchange between the populations has been developed and implemented. Quantitative criteria and timeframes for defining self-sustaining in more detail will be determined as more information becomes available.

2) Essential habitats, important migration routes, required streamflow, and water quality for the Virgin River habitat and the habitat of transplanted populations are legally protected, and the threats of other significant physical, chemical, or biological modifications such that the habitat would become unsuitable for the woundfin are removed.

Recovery Actions

The Recovery Plan consists of five major categories with 27 specific recovery actions and 17 subtasks as a means to achieve recovery. These actions are summarized below:

1) Maintain and enhance native fish communities of the Virgin River chub and woundfin, including:

- monitor native fish communities with emphasis on woundfin and Virgin River chub;
- eliminate nonnative fish species; and
- develop Virgin River chub and woundfin propagation reintroduction programs.

The Virgin River Fishes Recovery Implementation Team (Recovery Team) has monitored fish populations throughout the Virgin River since 1976 and developed a database to store that information. The Recovery Team is a collection of state, federal, and non-profit entities that review and implement recovery actions in the Recovery Plan. The VRP is a multi-agency cooperative partnership specifically designed to implement the Recovery Plan and the Virgin Spinedace Conservation Agreement and Strategy. The main goals of the VRP are to implement actions to recover, conserve, enhance, and protect native species in the Virgin River Basin, and to enhance the ability to provide adequate water supplies for sustaining human needs. The VRP has continued and expanded Recovery Team monitoring efforts in Utah, Arizona, and Nevada since 2002 (Fridell and Morvilius 2005a). These data are referenced later in our assessment of species' population status.

Three large-scale nonnative fish barriers (Webb-Hill, Stateline, and Virgin River Gorge) were constructed on the Virgin River main stem in Utah and Arizona (Virgin River Gorge) to assist in nonnative control. Several smaller scale barriers were constructed on washes and irrigation returns. The VRP, coordinating with the State of Arizona and others, later improved the Stateline and Virgin River Gorge barriers to improve their efficiency in preventing upstream migration of nonnative fishes.

The Recovery Team initiated red shiner treatments on the Virgin River in Utah, in 1988 and the VRP has taken over these activities since 2001. Red shiner (*Cyprinella lutrensis*) treatment activities have reduced the threat of expansion upstream of the Stateline barrier, but have yet to eliminate red shiner in Arizona and Nevada (refer to section 2.3.2.3 for more in depth discussion of these activities).

2) Protect and enhance habitat for the native Virgin River fish communities, including:

- monitor habitat conditions for native Virgin River fishes;
- develop and implement habitat improvements;
- develop instream flow recommendations needed to preserve native fish communities and their habitat;
- implement flow strategies and monitor response;
- establish gaging stations and monitor instream flows;
- identify existing water use and legal water rights within the basin;
- acquire high priority water rights;
- develop legally binding agreements to maintain instream flow; acquire land and/or easements along the Virgin River.

By 1902, more than 20 major irrigation diversions were operating on the Virgin-Muddy River system, and by 1910, flows were fully appropriated (USFWS 1994). Recommended recovery actions included securing water for instream flows to benefit Virgin River fishes. A minimum flow of 3 cubic feet per second (cfs) is secured below the Quail Creek Diversion through implementation of the Virgin River Spinedace Conservation Agreement (Lentsch et al. 1995). Return flows are also protected downstream to the Washington Fields Diversion (WFD) to meet the needs of irrigators and provide a biological benefit to Virgin River fish (USFWS 1982). In the Santa Clara River, 3 cfs is secured below Gunlock Reservoir via the Santa Clara pipeline project, which the VRP augmented with 2.5 cfs leased from the Shivwits Band of the Paiute Tribe in recent years.

Resource managers have determined that diminished flow continues to threaten woundfin and Virgin River chub throughout much of the river. Diminished flows are of particular concern from La Verkin Hot Springs to the Quail Creek Reservoir outflow at Stratton Pond in Utah, from the WFD downstream to the springs at the mouth of the Virgin River Gorge upstream of Littlefield, Arizona, and from the Mesquite Diversion downstream to the Halfway Wash in Nevada.

The VRP has collaborated with municipalities and others to purchase, or secure through easements, tracts of the Virgin River 100-year floodplain in Utah to protect against further habitat loss. Land prices throughout the Virgin River drainage have increased substantially in recent years making habitat acquisitions nearly as costly as securing flow. The VRP and other entities have pushed for local floodplain and erosion zone ordinances to protect the floodplain from development.

3) Establish additional populations of woundfin and Virgin River chub within their historic range, including:

- maintain genetically appropriate broodstock and refugia populations of woundfin and Virgin River chub at a minimum of two facilities;
- identify and prioritize reintroduction sites;
- develop reintroduction protocols;
- implement and monitor reintroduction of woundfin and Virgin River chub.

A genetically diverse brood stock of woundfin is maintained at the Southwest Native Aquatics Research and Recovery Center (SNARRC; formally known as Dexter National Fish Hatchery and Technology Center) in Dexter, New Mexico. This facility has produced fish for releases in the upper and lower river in accordance with approved reintroduction plans. The number of fish stocked per release has varied from a few hundred to in excess of 10,000 individuals. While stocked fish have reproduced in the wild, they have not persisted in the long term (see section 2.3.1.1).

Virgin River chub were also held at SNARRC and are currently held at the Wahweap Hatchery managed by the State of Utah. The VRP funded a study to characterize genetic diversity of the Virgin River chub brood stock relative to the wild population. The results of that study are characterized in Section 2.3.1.2 below.

In 1972, woundfin were transplanted into four locations in the Gila River system, but populations did not establish (USFWS 2008). In 1985, we established a 10(j) ruling (50 FR 30188, July 24, 1985) for further woundfin reintroductions in the Gila River drainage. Fish released in that drainage would be considered an experimental, nonessential population. These fish would not be afforded full protection under ESA. In the Recovery Plan, we recommended that the 10(j) ruling be withdrawn, due to the precarious status of the woundfin and we recommended that all future reintroductions receive full protection of the ESA. However, we have not taken any further actions on withdrawing the 10(j) rule. During the summer of 2007, the State of Arizona Game and Fish Department (AZGFD) stocked hatchery-reared woundfin in Hassayampa Creek (Gila River drainage) under the 10(j) ruling. Unfortunately, no woundfin were found in Hassayampa Creek since that reintroduction and are presumed extirpated.

4) Determine ecological requirements of native Virgin River fishes with emphasis on woundfin and Virgin River chub, including:

- define the genetic identity of Virgin River chub and woundfin;
- determine historical variation in population abundance of native Virgin River fishes;
- determine relationships between environmental conditions and recruitment;
- determine effects of habitat conditions on various life stages of Virgin River fishes;
- assess interaction between flow dynamics and food production;
- determine effects of timing, magnitude, and duration of flows and physical habitat;
- determine native fish community structure and interactions and migration movements;
- prevent loss or entrainment of fish in irrigation canals/diversions;
- further define downlisting and delisting criteria.

Monitoring of woundfin and Virgin River chub includes the entire fish community. The data set (1976 to present) shows strong correlations between environmental variables and relative abundance. See section 2.3.3.4 for more information.

Habitat degradation within the Virgin River system falls into three general categories including:

1. physical - flow depletions and elevated water temperature, manipulation of the channel and encroachment on the floodplain, and the effects of the invasion of nonnative riparian plants (e.g., tamarisk *Tamarix ramosissima*);
2. chemical - changes in water quality associated with surface runoff from agricultural, municipal, and industrial land use;
3. biological - introductions of nonnative fish species and parasites.

In 2009, the SNARRC completed a study (Chen et al. 2009) on woundfin and Virgin River chub captive population genetics. The study recommended some changes to broodstock population management to improve genetics of captive populations. See section 2.3.1.2 for more information.

In 2010, the VRP and the Washington County Water Conservancy District (WCWCD) began work on a pumpback system to augment river flow in the reach below the Hurricane hydropower plant in order to mitigate high water temperature conditions during summer months. The pumpback system was completed in 2012 and is used to augment river flows in the reach between the hydropower plant and WFD. Operation of the pumpback system has reduced the number of hours and days exceeding behavioral and critical water temperatures for woundfin and Virgin River chub. See section 2.3.3.2 for more information.

5) Develop and implement educational and informational programs highlighting recovery needs and ongoing efforts for Virgin River fishes, including:

- develop an information pamphlet describing these species and their biology, including the importance of the Virgin River to these species and other fish and wildlife, and reasons for preserving these species in nature;
- create a short film on the Virgin River ecosystem which presents a view of the ecosystem as a whole, in which the woundfin and Virgin River chub are an integral part; and
- use these materials to distribute information on the native Virgin River fish community to schools, visitor centers, and other civic organizations.

The Utah Division of Wildlife Resources (UDWR) annually visits 4th grade classrooms in Washington County to educate area schoolchildren about the importance of native Virgin River fishes and other species unique to the local ecosystem. UDWR has developed educational materials and has worked with area educators to implement these materials in school curriculums. In addition, the VRP funded a project to develop a community garden adjacent to the WCWCD administration building. The garden educates the public on water-conserving plants for home landscaping and includes viewable water tanks holding Virgin River chub, woundfin, and other native Virgin River fish species. The tanks include interpretive signs educating the public about Virgin River fishes and their importance to the area ecosystem.

2.3 Updated information and current species status

2.3.1 Biology and habitat

2.3.1.1 Woundfin and Virgin River chub biology and life history

Woundfin

Characteristics

The woundfin is a small scaleless minnow in the Cyprinidae family that occurs in the Virgin River, with shape and color characteristics adapted for living in swift, shallow, turbid, sandy-bottomed streams (Miller and Hubbs 1960; Williams and Deacon 1998). Average total length ranges between 60 to 85 millimeters (mm) [2.4 to 3.4 inches (in)] with a maximum total length of approximately 110 mm (4.3 in). Sexually mature individuals are tuberculated (small protruding knobs on fins) and have yellow coloring near the insertion of the pectoral, pelvic, and anal fins.

Reproduction/Recruitment/Survival

Woundfin reproduction is triggered by spring runoff, with spawning occurring on the descending curve of the hydrograph. Spawning occurs in moderate to swift velocity run habitat over fine gravel substrate; these areas typically occur downstream of riffles or pools (Fridell and Bennion 2019). Spawning locations are driven primarily by substrate composition rather than habitat type or depth (Fridell and Bennion 2019). During spawning, woundfin exhibit tight schooling behavior in run habitat (7 to 10 centimeters (cm) deep; 2.8 to 3.9 in) and eggs approximately 1.5 mm in diameter (0.06 in) are deposited in small rock substrate that is 5 to 10 cm in diameter (2.0 to 3.9 in) (Greger and Deacon 1982). Under experimental conditions, woundfin eggs take 5 to 11 days to develop, and juveniles reach a total length of 56 mm (2.2 in) in four months (Greger and Deacon 1982; Webb et al. 2010). In the river, growth is temperature dependent; if water temperatures remain greater than 10 to 12°C (50.0 to 53.6°F), woundfin can grow throughout the year (Fridell and Bennion 2019). In years with average runoff occurring in April, young woundfin grow to reproductive maturity (66 mm; 2.6 in) by late fall (October or November; Fridell 2016).

Woundfin size prior to spring runoff is directly related to the reproductive success and population size for the subsequent year (Fridell and Morvilius 2005b). Based on observations in the river, woundfin must achieve a total length of 66 mm (2.6 in) or greater prior to the spring spawning season to contribute to recruitment (Fridell and Morvilius 2005b). Most recruitment of woundfin occurs in a 26.3 kilometer (km) [16.3 mile (mi)] reach of the Virgin River from La Verkin Springs to the WFD, which correlates to areas within the historical range that are free of red shiner (*Cyprinella lutrensis*) (Fridell and Morvilius 2005b).

Of all Virgin River fish, woundfin are the most dependent on good (above average) water years. Reproduction, survival, and recruitment are directly correlated to years with above average spring runoff (i.e., above average or high water years) (Fridell and Bennion, 2019). However, high water years can cause delayed reproduction if the runoff is protracted, which can lead to reduced recruitment and survival. For example, spring runoff in 2005 extended through June and reproduction occurred much later than normal (Fridell and Bennion, 2019). In August, young woundfin only measured 15 to 30 mm (0.6 to 1.2 in), and by December a majority of these individuals were still < 40 mm (1.6 in). Subsequently, many of these fish did not survive over winter, and those that did were too small to reproduce in spring 2006. In years with limited or no spring runoff, reproduction, recruitment, and survival is minimal (Fridell and Bennion, 2019).

Summer flows can also impact woundfin survival and recruitment. High instream temperature combined with low streamflow result in lower reproduction success and survival rates (Fridell and Bennion, 2019). Conversely, summer monsoons can cause high pulse events that displace young woundfin into population sink reaches downstream (i.e., areas with red shiner or dewatering), thereby eliminating recruitment of these fish (Fridell and Bennion, 2019). The elimination of the lower river population of woundfin may also be a function of declining populations upstream (i.e., lack of downstream drift from upstream areas; Holden et al. 2001).

Life Span

Since the 1990s, age composition for woundfin has shifted towards younger fish (Fridell and Bennion, 2019). While we do not fully understood why age composition has changed, it is likely caused by environmental stressors, especially high water temperatures. As described in Section 2.3.3.1, high summer water temperatures have reduced survival of woundfin in the Virgin River. Coupled with stocking of age-1 fish in the Virgin River, these factors have shifted age composition. By 2002, second-year and older age classes of woundfin comprised less than 5 percent of the total woundfin population in the upper Virgin River (UDWR unpublished data 2015). Only an extremely small percent (< 1 percent) of wild woundfin live to be > 1-year old; however, in the hatchery, woundfin can live to be ≥ 4-years old (Fridell and Bennion, 2019). The Virgin River woundfin population largely consists of a single age class (i.e., 1-year old or less), and persistence is dependent on the survival and reproductive success of these young fish (Fridell and Bennion, 2019).

Habitat

Young woundfin (including larval, fry, and juvenile) use low velocity areas that provide cover and are highly productive (e.g., small inflows and shallow slackwater margins; Fridell and Bennion, 2019). As woundfin grow, they use higher velocity habitats. Adult woundfin are typically found within shallow to deep sandy runs, but use less optimal habitat as necessary (Fridell and Bennion, 2019). Woundfin shift habitat use seasonally, moving from typical run habitat, seeking covered areas in winter (e.g., undercut banks, inundated or submerged vegetation, silt substrate) and thermal refuge areas during summer (e.g., cool water inflows, seeps, pools, springs, tributary mouths, groundwater recharge areas below riffles). Woundfin also shift habitat use during high clarity or high temperature conditions, moving from preferred habitat to refuge areas with cover (Fridell and Bennion, 2019). For example, when water clarity is high, woundfin congregate in deeper run or pool habitats. This shift in habitat use during stressful high water temperature periods can limit the survival of all woundfin age classes by reducing their ability to forage (and consequently their fitness) and increasing risk of predation (Fridell 2016).

The water temperatures preferred by woundfin range from 11 to 24°C (51.8 to 75.2°F; Schumann 1978). The temperature that woundfin start to modify their behavior is identified as the behavioral thermal maximum (BTM), which occurs at 28°C (82.4°F; Rehm et al. 2006). Virgin River fishes lose equilibrium when exposed to temperatures of 31°C (87.8°F; Deacon et al. 1987), thus establishing this temperature as a critical thermal maximum (CTM). In a controlled environment with rationed food allocations, a positive relationship between water temperature and growth exists between 10.4°C and 26.6°C (50.7 and 79.9°F) for woundfin; however, if adequate food is available, woundfin can survive indefinitely at temperatures $\leq$ 29.5°C (85.1°F; Addley et al. 2005). Temperatures above this threshold cause physiological limitations and subsequent mortality for wild woundfin in the river.

Woundfin distribution is also influenced by streamflow regimes that include high and low flow episodic events that create changes in habitat and substrate. In years with limited sand substrate, woundfin move in search of this substrate type (Fridell and Bennion, 2019). For example, in 2012, sand substrate decreased in the upper Virgin River resulting in the downstream movement of woundfin. Monitoring by UDWR tracked the gradual downstream movement of the 2012 woundfin population through the year. In spring 2012, woundfin were concentrated in the La Verkin Springs to WFD reach. By summer they moved into the Johnson Diversion to Webb Hill Barrier reach, and by fall they were in the Stateline Barrier to Virgin River Gorge Barrier reach. Conversely, in 2015, sand substrate was well distributed in the upper Virgin River and remained throughout the year; woundfin persisted in these reaches and did not move downstream (Fridell and Bennion, 2019).

Diet

Woundfin are omnivorous, with diet consisting of various aquatic invertebrates, plant matter, and detritus (Cross 1975). Woundfin can shift their diet in response to diel and seasonal availability (Greger and Deacon 1987). During low flow periods, when food abundance is minimal, woundfin feed almost continuously over a 24 hour period (Greger and Deacon 1987). This feeding behavior may enable woundfin to survive during stressful temperature extremes; however, this may also make woundfin more susceptible to limiting factors associated with high water clarity (Addley et al. 2005). Dietary overlap among Virgin River fish species is generally low, indicating considerable resource partitioning even during times of lowest resource availability; however, dietary overlap between woundfin and the invasive red shiner occurs during fall and winter (Greger and Deacon 1988).

Virgin River Chub

Characteristics

The Virgin River chub is a medium sized, small-scaled silvery minnow in the Cyprinidae family, endemic to the Virgin River (Utah, Arizona, and Nevada) and the Muddy River (Nevada). Average total length for this species is approximately 200 mm (7.9 in) with a maximum total length of 450 mm (17.7 in) (USFWS 1994).

Reproduction/Recruitment/Survival

Spawning typically occurs in late spring; however, Virgin River chub reproduction is less correlated with spring runoff than it is for woundfin, and spawning events can occasionally occur during summer months (Fridell and Bennion, 2019). During spawning, Virgin River chub congregate downstream of riffles in plunge pools or deep runs, with large adults contributing to a majority of the reproducing population (Fridell and Bennion, 2019). Unlike woundfin, substrate composition does not seem to be an important factor in determining spawning location.

Upon hatching, Virgin River chub fry drift downstream and collect in slow moving eddy and backwater habitats. These habitats provide ideal conditions for rearing as the shallow water increases food availability and reduces competition or predation from nonnative fishes (Fridell and Bennion, 2019). As they grow, young Virgin River chub gradually move into deeper habitats with higher velocities. During good reproduction years in the La Verkin Springs to WFD reach, monitoring has documented significant downstream drift of young Virgin River chub (Fridell and Bennion, 2019). Regardless of water year, young Virgin River chub drift as far downstream as the Virgin River Gorge (and likely downstream to Nevada). Pulse events caused by summer monsoons can also cause additional and significant downstream drift (Fridell and Bennion, 2019). Virgin River chub likely evolved to use drift as part of their strategy, and thus are likely more susceptible than other native species to the negative impacts of habitat fragmentation (i.e., fish barriers and water diversion structures).

Adult Virgin River chub show a large degree of variation in movement patterns. Some Virgin River chub appear to be relatively static in the mainstem Virgin River, as documented by pit-tagged individuals captured in the same pool over multiple years in the reach between La Verkin Springs and the confluence of La Verkin Creek (Fridell and Bennion, 2019). Conversely, some Virgin River chub move into the upstream reaches of tributaries, as documented by individuals captured in the upstream reaches of La Verkin Creek. Adults also move into off channel areas, ditches, and canals, as well as upstream of La Verkin Springs during high flow periods (Fridell and Bennion, 2019). Large adults have been captured downstream of rotenone treatments to remove nonnative fish, demonstrating large-scale downstream movements in response to the treatment (Fridell and Bennion, 2019).

In comparison with woundfin and other Virgin River fish species, Virgin River chub survival is less influenced by annual changes in river conditions (Fridell and Bennion, 2019). This is most likely due to a combination of factors including size, longevity, diet, behavior, and movement. Reproduction and recruitment occur during harsh summers with low streamflow and high clarity; however, the best reproduction and recruitment occur during above average or high water years (Fridell and Bennion, 2019). Virgin River chub populations also respond positively following large channel forming events (i.e., events that scour and create deep pools). Years with channel forming or habitat maintenance flows are good for Virgin River chub reproduction and recruitment, whereas years without these events correlate to a decrease of pool habitat and an increase in the downstream movement of Virgin River chub (Fridell 2016).

Life Span

Virgin River chub are a long lived species, living an estimated 10 years or more in the wild (USFWS 1994). Growth is dependent on environmental conditions and spawning time. Virgin River chub reach sexual maturity in 1 to 2 years (averaging 95 to 110 mm in total length; 3.7 to 4.3 in). Like woundfin, sexually mature Virgin River chub are tuberculated, but also have pink coloring on the pectoral, pelvic, and anal fins. Due to their longevity and ability to adapt to varied habitat conditions, Virgin River chub are less susceptible to stochastic events and typical changes than other native Virgin River fishes (USFWS 1994). This results in Virgin River chub having a higher tolerance to a wider range of conditions that limit the survival of other native fish species.

Habitat

Although there is some segregation of age classes by habitat type, no preference has been detected among age class and substrate type (Golden and Holden 2005). Adult Virgin River chub prefer deep water habitats of slow to moderate velocity, containing boulders and other instream cover (Hardy et al. 1989, Fridell and Morvilius 2005a). Populations are stratified with larger adults using the deepest pools and juveniles using deep runs or shallow pools. Although adult Virgin River chub use deeper pool habitat, they will also forage in run habitats.

Virgin River chub appear to be more nocturnally active than other native Virgin River fishes (Fridell and Bennion, 2019). This strategy provides more opportunity for foraging and survival of young during conditions when there is low streamflow, high temperature, and high clarity. Comparatively woundfin are more restricted and seek thermal refuge during these types of conditions (Fridell and Bennion, 2019).

Adult Virgin River chub choose water temperatures around 24°C (75.2°F) (Schumann 1978; Deacon et al. 1987). Virgin River chub have a narrower optimal thermal tolerance than woundfin, ranging between 17 to 28°C (62.6 to 82.4°F). However, the thermal maxima identified for woundfin (i.e., BTM of 28°C and CTM of 31°C; 82.4°F and 87.8°F) appears to be valid for all native Virgin River fish species (Huizinga and Fridell 2012).

Diet

Virgin River chub are opportunistic omnivorous feeders, and have shown considerable dietary shift with age and season (Greger and Deacon 1988). Overall, their diet consists of algae, invertebrates, and smaller fish (USFWS 1994). Young Virgin River chub (40 to 70 mm; 1.6 to 2.8 in; n=8) feed predominantly on macroinvertebrates, while adults (>110 mm; 4.3 in; n=22) consume mostly algae and debris (i.e., sediment and detritus; Greger and Deacon 1988, Cross 1975).

2.3.1.2 Genetics

The Recovery Plan identifies maintaining genetically viable broodstock and refugia populations of woundfin and Virgin River chub as an integral part of the reintroduction and supplementation of Virgin River chub and woundfin within their historical range (USFWS 1994). Guidelines for maintaining genetic diversity within these captive populations were established in the salvage, broodstock, and culture plans for woundfin and Virgin River chub (Hepworth et al. 2000, Morvilius and Fridell 2006). These guidelines were developed in accordance with the Recovery Plan in order to implement a hatchery program and utilize cultured fish to supplement wild populations.

In order for the established broodstock and refuge populations to assist in the recovery of these species, genetic studies were needed to establish a baseline genetic structure for both woundfin and Virgin River chub, and to ensure that natural gene frequencies were not altered among wild and captive populations (USFWS 1994). Between 1992 and 2006, genetic studies were completed for woundfin and Virgin River chub and the results are discussed below. A summary of the history of woundfin and Virgin River chub broodstock and refuge populations and stocking efforts and accomplishments can be found in section 2.3.3.5.

Woundfin

In 2006, the genetic variation between captive and wild woundfin was evaluated by Southwestern Native Aquatic Resources and Recovery Center (SNARRC) (Chen et al. 2009). After 20 years of captive propagation, wild woundfin were genetically similar to the captive population and captive woundfin were not impacted by the founder effect or genetic drift. Overall, the study showed that woundfin exhibit high levels of genetic variation. Although statistically significant differences occurred between captive and wild woundfin, these levels were low enough to not be of management concern, and were a reminder that divergence can occur if the captive broodstock is not genetically managed.

The SNARRC study also evaluated the genetic contribution of captive woundfin to wild woundfin (Chen et al. 2009). During 2005, stocked woundfin contributed to 48 percent of the recruitment in the Virgin River near Quail Creek and 39 percent in the reach above WFD (Chen et al. 2009). These findings provide strong evidence that stocking from captive populations in 2003 and 2004 supplied genetic material to the wild population, and increased the number of woundfin in the Virgin River (Schijf et al. 2004; Fridell and Morvilius 2005b).

As a result of the genetic study, Chen et al. (2009) recommended pooling multiple year classes of captive woundfin to prevent and mitigate the effects of temporal variation (Whitlock 1992), and collecting tissue samples for comparison with the baseline in future genetic analyses. Additional recommendations included supplementing the refuge population with approximately 300 individuals from throughout the range of the species every 2 years to counter the effects of genetic drift. To date, the VRP has largely implemented these recommendations to improve genetic diversity of captive woundfin populations in hatcheries.

Virgin River Chub

To date, two genetic studies on Virgin River chub have been conducted. The first study examined morphological and genetic characters from three populations of the genus *Gila* and concluded that the Virgin River chub found in the Virgin River and Muddy River comprise a distinct species (DeMarais et al. 1992). Genetic diversity of Virgin River chub declined in the lower Virgin River because of substantial mortality following a rotenone treatment in 1988, wherein detoxification failed and fish were killed from the Virgin River Gorge downstream to Mesquite, Nevada (DeMarais et al. 1992).

The second study was conducted in 2008 by SNARRC to investigate population structure within the range of the species, compare the genetics of wild and captive populations, and characterize extant levels of genetic variation (USFWS 2008b). The study showed a low level of divergence in Virgin River chub between the upper and lower Virgin River. There was also little divergence between wild and captive Virgin River chub, and this outcome is not surprising since the Virgin River was the source for the captive population at SNARRC. The majority of genetic variation was within individuals (98.74 percent) verses between sites (1.26 percent). This indicates that during the 19 year captive management of Virgin River chub, genetic drift has acted on all populations (USFWS 2008b).

The upper Virgin River population also went through a likely genetic bottleneck a few years later, declining in abundance by greater than 90 percent from 2006 to 2007 in response to hypoxic conditions stemming from input of run-off from burned areas of the watershed during large storms (Huizinga et al. 2011). Recovery of the population to predisturbance levels required extensive stocking of hatchery-reared fish, which also had low genetic diversity (DeMarais et al. 1992). These events may have permanently depressed the genetic diversity of Virgin River chub throughout the Virgin River.

Although there was little divergence between captive and wild Virgin River chub and between populations in the upper and lower Virgin River, the Muddy River population was moderately divergent and genetically distinct from populations in the Virgin River. Therefore, the Muddy River population may need to be considered a separate management unit. It is unknown if the divergence between the Muddy and Virgin River populations occurred naturally or is the result of fragmentation caused by Lake Mead. Unfortunately, due to the absence of genetic samples prior to the building of the Hoover Dam and subsequent creation of Lake Mead, it is not possible to determine the cause of this divergence (USFWS 2008b).

Based on the study by SNARRC (USFWS 2008b), the following recommendations were made for Virgin River chub: 1) manage the Muddy River population as a separate management unit since it is moderately divergent from Virgin River populations; 2) conduct regular translocations of Virgin River chub from lower sections to upstream sections if manmade structures are restricting upstream movement; and 3) continue supplementing wild Virgin River chub (i.e., 200 fish every 3 – 4 years) to the captive broodstock to reduce the risk of genetic divergence between captive and wild populations. To date, the VRP has largely implemented these recommendations to improve genetic diversity of Virgin River chub populations.

2.3.1.3 Taxonomic classification or changes in nomenclature

Woundfin

The woundfin was originally classified and described by Cope (1874). These specimens were identified as being collected in the San Luis Valley in western Colorado by the Wheeler expedition. However, due to errors made by that expedition, it is more likely the specimens were collected from the Virgin River in Utah (Miller and Hubbs 1960).

The woundfin belongs to a monotypic genus and is considered the most highly specialized species in the cyprinid tribe Plagopterini (Miller and Hubbs 1960). Its entire taxon is endemic to the lower Colorado River Basin.

Virgin River Chub

The Virgin River chub is a medium sized minnow that was first described by Cope and Yarrow (1875) and these specimens were collected in the Virgin River, south of Washington, Utah. While it was determined to be an intermediate species between the roundtail chub (*Gila robusta)* and the bonytail chub (*Gila elegans*), some considered it a subspecies of roundtail chub (*Gila robusta seminuda*) (Ellis 1914; Miller 1946; La Rivers and Trelease 1952). Holden and Stalnaker (1970) and Minckley (1973) later indicated that the Virgin River population was a valid subspecies, and Smith et al. (1979) supported this conclusion with extensive taxonomic analyses.

In 1989, the Virgin River chub was still considered a subspecies of the roundtail chub when it was listed, and the USFWS recognized that a closely related form of roundtail chub (presumably an undescribed species) was found in the Muddy River (Moapa River) in Nevada. In 1992, a review of morphological and genetic characteristics determined that the Virgin River chub is a full species, which includes the Muddy River population (DeMarais et al. 1992). This work supported a full species ranking for the Virgin River chub by the American Fisheries Society (Nelson et al. 2004).

2.3.1.4 Spatial distribution and range

Woundfin

The historical range of woundfin includes the Virgin River and its tributaries in Utah, Arizona, and Nevada (La Rivers 1994; Figure 1). In the mainstem Virgin River, woundfin were distributed from the confluence of the Colorado River upstream to La Verkin Springs in Utah. It is possible that woundfin distribution extended upstream of La Verkin Springs, although no records exist. In addition to the Virgin River mainstem, woundfin were distributed in La Verkin Creek. Woundfin may have been present in the Colorado River downstream of the Virgin River confluence and in the Gila River, but it is unclear if their distribution in these rivers was a common or occasional occurrence. Although woundfin were historically recorded in the Gila River Basin, we are not considering this to be part of their historical distribution because there are only three records from the Gila River system and the most recent is from 1894 (Miller 1952).

Currently, the only viable population of woundfin occurs within a 26.2 km (16.3 mi) reach in the upper Virgin River between Ash Creek and WFD (Fridell and Bennion, 2019). Woundfin are occasionally found downstream of this reach to the confluence of the Beaver Dam Wash in Arizona (Figure 1), with individuals periodically captured downstream into Nevada. The sporadic distribution of woundfin in the lower Virgin River is the result of drift following good reproduction years in the upper Virgin River; however, woundfin rarely persist or reproduce in the lower Virgin River due largely to low instream flows, predation and competition from nonnative fishes (Fridell and Bennion, 2019).

Virgin River Chub

The historical range of Virgin River chub included the Virgin River and Muddy River systems in Utah, Arizona, and Nevada (Figure 2). In the mainstem Virgin River, their distribution extended from the confluence of the Colorado River upstream to approximately 4.7 km (2.9 mi) above La Verkin Springs in Utah. The species also occurred in La Verkin Creek.

Virgin River chub currently occur in the mainstem Virgin River downstream of La Verkin Springs to the confluence of Beaver Dam Wash. Small numbers of the species occur sporadically downstream of Beaver Dam Wash (Figure 2). In the Muddy River, Virgin River chub are found in an approximately 30.0 km (18.6 mi) reach between Warm Springs Bridge and Wells Siding Diversion (Figure 2).

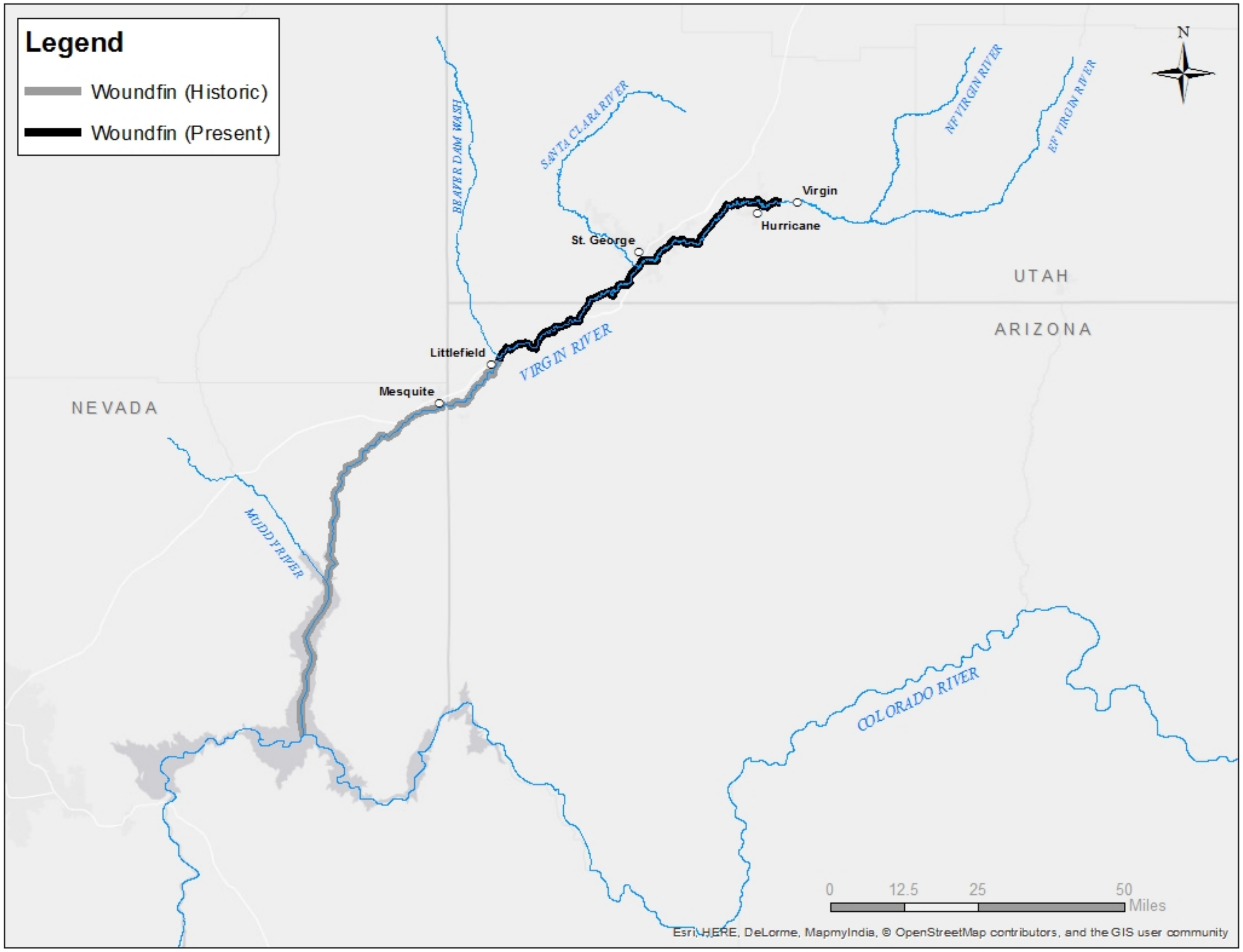

Figure 1. Historic and present distribution of woundfin in the Virgin River system within the lower Colorado River drainage in Utah, Arizona, and Nevada.

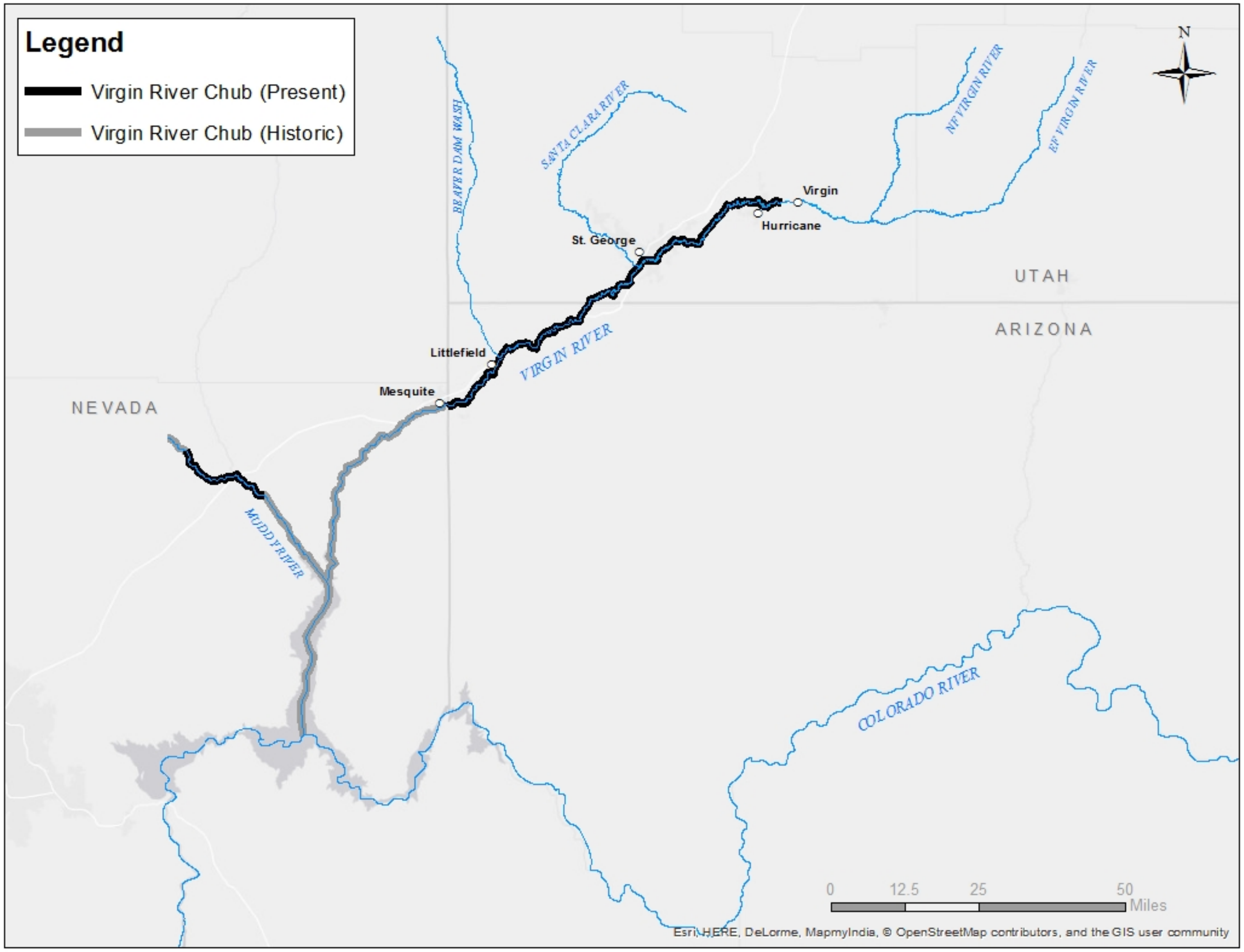

Figure 2. Historic and present distribution of Virgin River chub in the Virgin and Muddy River systems within the lower Colorado River drainage in Utah, Arizona, and Nevada.

2.3.1.5 Population trends, demographic features, or demographic trends

A collection of biotic and abiotic factors have reduced native fish populations in the Virgin River system. The decline of native fish abundance and distribution resulted in the listing of woundfin and Virgin River chub as endangered under the ESA (USFWS 1994). Multiple monitoring projects were established since the listing of both species and are explained below.

The first monitoring of woundfin and Virgin River chub populations began in the 1970s with the establishment of the several Recovery Team monitoring stations. After the establishment of the VRP in 2002, the VRP continued and expanded Recovery Team monitoring efforts and also funded multiple new monitoring projects to evaluate native fish populations throughout the Virgin River in Utah (upper Virgin River). A majority of these projects were designed to better assess native fish population status and identify factors restricting their abundance and distribution throughout the upper Virgin River. Specific ongoing monitoring projects include: full pass distribution between La Verkin Springs and WFD (full pass), population response stations (PRS), and Virgin River chub hoop net monitoring.

Similarly, in the lower Virgin river (Arizona and Nevada), a variety of interested agencies and contracted private consultants have increased monitoring efforts to bolster the Recovery Team monitoring and answer specific research and management questions. Results of these more rigorous monitoring efforts are used to test the validity of established, but less intensive Recovery Team monitoring data to track population trends.

Monitoring is also used to determine effectiveness of management actions including detecting nonnative fish species and taking corrective actions; determining timing, fish size, and numbers needed for stocking; evaluating and fine tuning release patterns for instream flow management; and refining sluicing protocols. The overall goal of these collective monitoring projects is to evaluate woundfin and Virgin River chub population status and identify potential areas for improvement through management actions in the upper Virgin River mainstem. Monitoring associated with these management actions also allows for the collection of long term data on species composition, age structure, and relative abundance.

In order to summarize woundfin and Virgin River chub status for this review, data sets from Recovery Team, full pass, PRS, and Virgin River chub monitoring were examined and used to show trend data for both species. These monitoring projects represent the most comprehensive trends for population status of woundfin and Virgin River chub. The remainder of this section examines the data collected during each of these monitoring projects by stream reach.

For all fish abundance and trend data described in the following subsections, there have been events over the past 40 years that may have influenced woundfin and Virgin River chub distribution and catch rates in the upper Virgin River. To aid in the interpretation of these data, a list of important or unique events are summarized below. Additional details and extent of impacts from these events are discussed in Sections 2.3.2 and 2.3.3 below.

- Red shiner colonization – 1980s
- Quail Creek Diversion completed – 1985
- Rotenone treatments – 1988 to 2014 (various reaches between Washington Field Diversion and Virgin River Gorge Barrier)
- Quail Creek Dam failure – December 31, 1989
- Low water years (below average spring runoff/drought years; < 65 percent of average) – 1989, 1991, 1996, 2000, 2003, 2004, 2007, 2013, 2014, 2015
- Extremely low water years (< 50 percent of average) – 1976, 1977, 1990, and 2002
- Extremely high water years (> 115 percent of average) – 1973, 1978, 1979, 1980, 1982, 1993, 1995, 1998, and 2011
- Exceedingly high water years (> 200 percent of average) – 2005
- Poor water quality events – September 2003, July 2004, July 2006, July 2007, August 2007 (see section 2.3.3.1)
- Flash flooding post-fire – July 2007 (see section 2.3.3.1)
- Woundfin stocking – 2003 – 2015 (see section 2.3.3.5)
- Virgin River chub stocking – 2006 – 2015 (see section 2.3.3.5)

To improve comparability of catch rates across stations and years, only data sets collected in the fall (September to October) were considered for evaluation for each monitoring project. Monitoring during this time follows periods of reduced discharge, elevated instream temperatures, and low turbidity. These conditions are the factors that limit native fish populations (see section 2.3.3.1 and 2.3.3.4). Therefore, fall data represents native fish survival after exposure to the most severe abiotic environmental conditions and reflects a more accurate population abundance estimate for each species.

To reduce variability among collection methods and data sets for Virgin River fish, catch rate is the standardized metric used (number of fish per seine haul) to show long-term trends for seine-based monitoring (Holden et al. 2001). All catch rates presented in the subsections below were transformed by adding one to the natural logarithm (*ln*+1) to reduce the amount of variance in each dataset. In addition to catch rate, the total number of woundfin and Virgin River chub are also provided. Woundfin and Virgin River chub population trends for each stream reach are discussed in further detail below.

Ash Creek to WFD:

Recovery Team Monitoring

Recovery team monitoring methods were specifically designed to target fish in woundfin habitat. However, the original purpose was to determine the population status of all native Virgin River fish species. Although this data set is less robust than more recently designed monitoring efforts, it is the longest running data set and is still useful in detecting large scale shifts and trends in all native fish populations, including woundfin and Virgin River chub, in the Virgin River.

Ten recovery team stations were established on the mainstem Virgin River: six in Utah (Figure 3), two in Arizona, and two in Nevada. The stations in the upper Virgin River include:

- Near Ash Creek;
- Above Quail Creek;
- Below Hurricane Bridge;
- Above Washington Fields Diversion (AWFD)
- Above River Road Bridge (Twin Bridges); and
- Bloomington.

Stations in the lower Virgin River include:

- Beaver Dam Wash (BDW, AZ);
- Cedar Pocket (AZ);
- Mesquite Diversion (AZ); and
- Riverside Bridge (NV).

Three of these 10 stations are included in the data summary below; Near Ash Creek, Twin Bridges, and Beaver Dam Wash. These stations were selected for two reasons: 1) they represent population trends observed in recovery team monitoring for the upper and lower Virgin River; and 2) these stations were consistently monitored since the 1970s. This data summary only assesses woundfin at the Twin Bridges station, Virgin River chub at the Near Ash Creek station (see Virgin River chub Hoop Net Monitoring section below), and both species are assessed in the Beaver Dam Wash station.

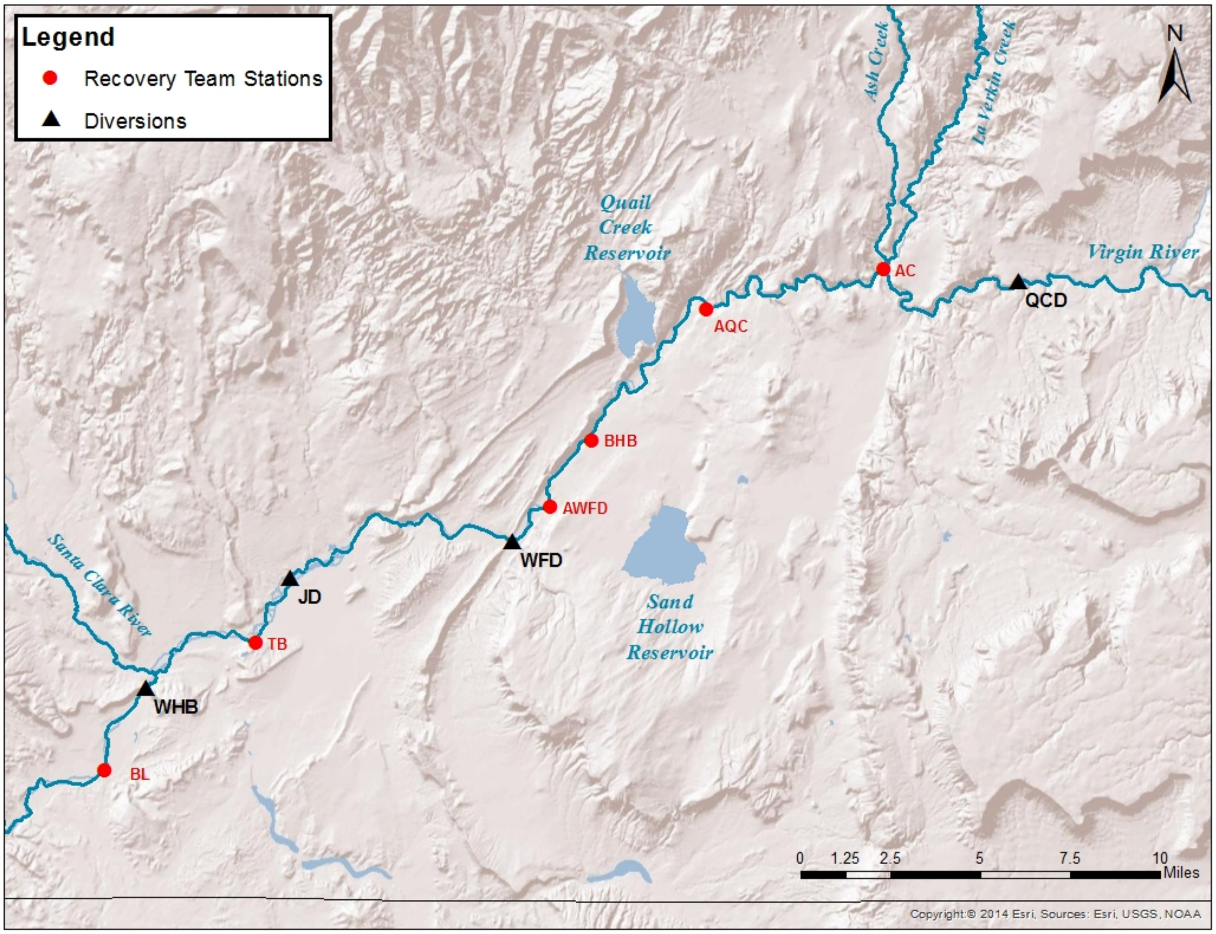

Figure 3. Recovery Team Monitoring Stations in the upper Virgin River basin. Map includes the Near Ash Creek (AC), Above Quail Creek (AQC), Below Hurricane Bridge (BHB), Above Washington Fields Diversion (AWFD), Twin Bridges (TB); and Bloomington (BL) stations. Note: Quail Creek Diversion (QCD), Washington Fields Diversion (WFD), and Johnson Diversion (JD), shown for reference; Webb Hill Barrier (WHB) is also included for reference; however, it no longer exists (i.e., sedimentation following high flows in December 2010).

Between Ash Creek and WFD, other data sets better represent woundfin population trends than recovery team monitoring. These data sets are discussed below. In addition, although Virgin River chub captures are recorded, due to the bias in Recovery Team monitoring methods (i.e., targeting sandy run habitat preferred by woundfin), Virgin River chub populations are also better represented in the other data sets (full pass, PRS, and Virgin River chub hoop net monitoring). In the lower Virgin River basin, no data sets are available that provide long-term monitoring of Virgin River chub, so we included the data on Virgin River chub captures at the Beaver Dam Wash station to show population trends for that stream reach below.

Population Response Station Monitoring

Population response station (PRS) monitoring were initiated in 2003 following intensive red shiner removal surveys above WFD. Originally, four 2.4 km (1.5 mi) stations were established in representative river reaches to obtain baseline fish population data on a monthly basis (above WFD, Quail Creek, Ash/La Verkin, and Grafton). An additional station was established below WFD in 2005 to monitor fish response to the new WFD fish screen and return flows below the WFD. In 2007, the Twin Bridges station was established below Johnson Diversion following the successful removal of red shiner. In 2011, the Nature Conservancy funded the establishment and implementation of the Man-O-War station in Bloomington, which was designed to monitor native fish recovery efforts in a reach previously colonized by red shiner (Figure 4).

These stations are also coordinated to monitor population responses and determine effectiveness of management actions including:

- detecting nonnative fish species and taking corrective actions;
- success of woundfin stocking;
- determining timing, fish size, and numbers needed for stocking;
- evaluating and fine tuning release patterns for instream flow management;
- refining sluicing protocols.

Originally, PRS monitoring were used to monitor distribution of red shiner between systematic full pass distribution surveys. After red shiner were eradicated from the upper Virgin River, PRS monitoring was primarily used to collect information to help identify distribution of native fish, particularly woundfin, under varying flow and habitat conditions. Monitoring was originally conducted monthly from February to November (2003 to 2014); in 2015, monitoring was conducted six times between March and October.

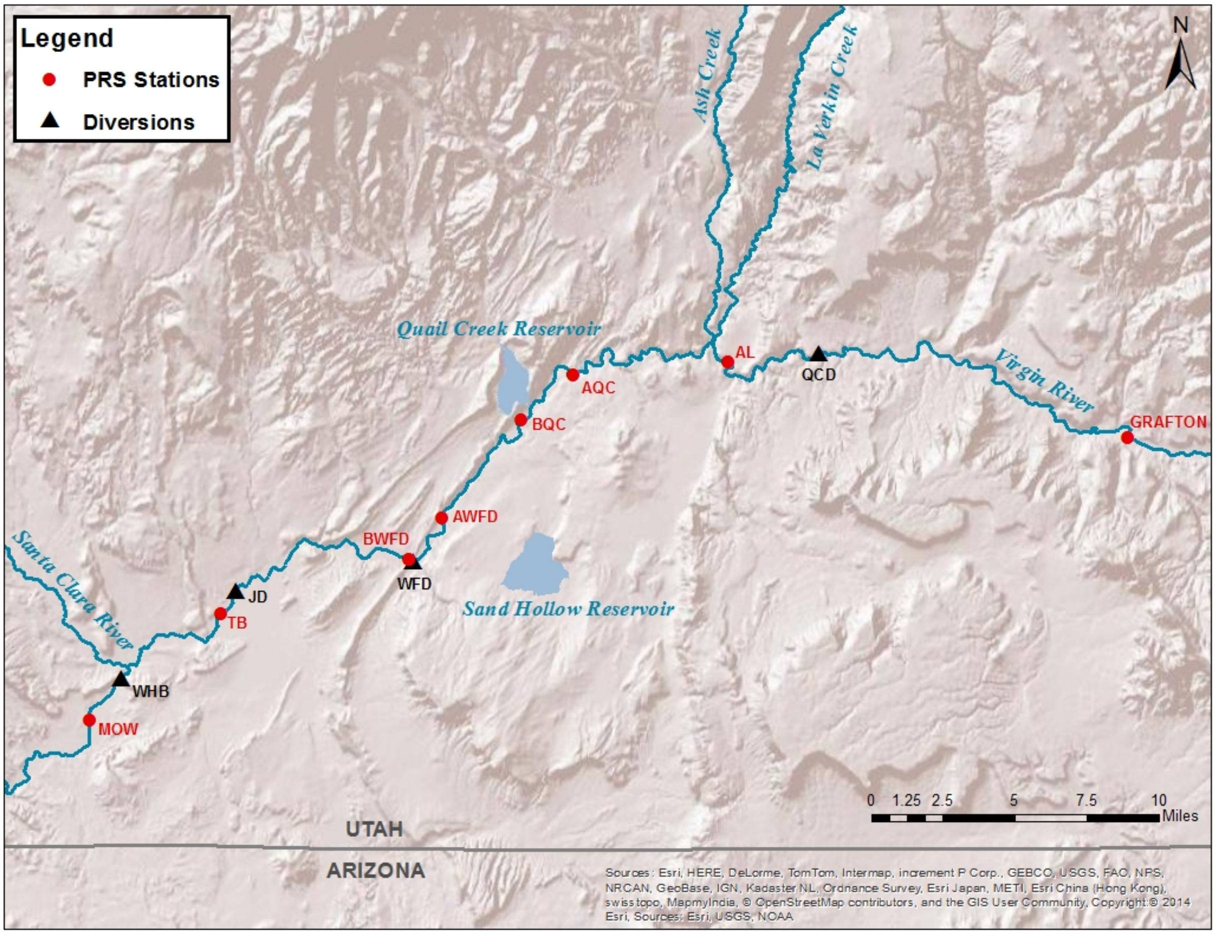

Figure 4. Population Response Stations in the upper Virgin River basin. Map includes the Grafton, Ash – La Verkin (AL), Above Quail Creek (AQC), Below Quail Creek (BQC), Above Washington Fields Diversion (AWFD), Below Washington Fields Diversion (BWFD), Twin Bridges (TB); and Man-O-War (MOW) stations. Note: Quail Creek Diversion (QCD), Washington Fields Diversion (WFD), and Johnson Diversion (JD); Webb Hill Barrier (WHB) is also included for reference; however, it no longer exists (i.e., sedimentation following high flows in December 2010).

Population monitoring was conducted in 50 random sites at each station in proportion to the percent of each habitat type available (see section 2.3.3.2 for information on habitat monitoring methodology). Prior to each PRS monitoring period, a random number generator was used to select the subset of habitat polygons designated for monitoring (Bennion et al. 2008; Bennion and Fridell 2009). For each habitat unit monitored by seine haul, all captured fish were enumerated and categorized by species and age class (e.g., adult and young). Catch rates were calculated by summing the total number of fish captured at each station by species and monitoring period and dividing by the total number of samples.

To examine woundfin and Virgin River chub trends in the PRS dataset, three of the four original stations were chosen (Ash/La Verkin, Quail Creek, and above WFD). These locations were chosen because they have the longest data set and best represent the reaches above the WFD. To aid in comparison with other data sets, only the first monitoring during fall (September or October) was used. The Grafton station was excluded since it is upstream from woundfin and Virgin River chub historical distributions. A full summary of PRS monitoring can be found in Bennion and Fridell (2015). A summary of woundfin and Virgin River chub numbers and catch rates by station from 2003 to 2015, is provided in Appendix B.

The woundfin and Virgin River chub abundance in fall PRS monitoring between 2003 and 2015 mirror those of other monitoring efforts (Figures 5 and 6). While this is not surprising, as monitoring during one period each fall should depict the same annual fluctuations, the PRS data set provides a comparison among stations that are randomly monitored in proportion to the habitat available. Woundfin catch rates were highest at above WFD for most years. However, the Quail Creek results were highest in 2008 and 2009, and the Ash/La Verkin site was highest in 2006, but equal to above WFD in 2012 (Figure 5, Appendix B). Virgin River chub catch rates were highest at Ash/La Verkin for all years except during 2011 to 2013, when Quail Creek catch rates were highest (Figure 6, Appendix B). Overall, catch rates for both species during 2005 and 2011, were caused in part, by a large reproductive event following high spring flows (Bennion and Fridell 2006; Bennion and Fridell 2012).

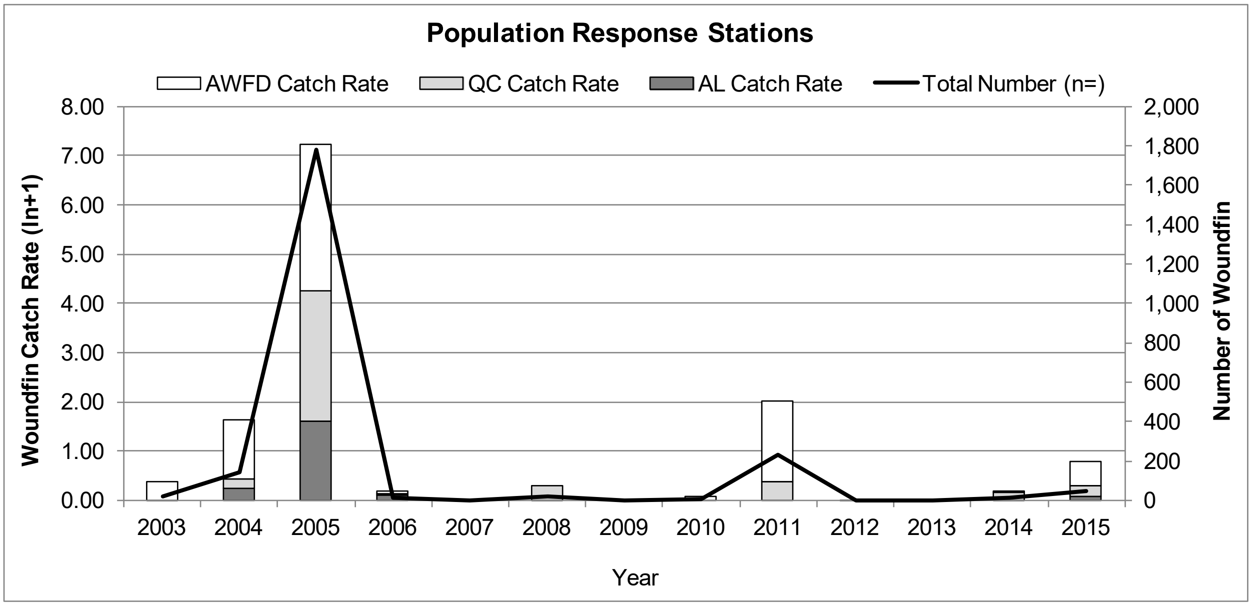

Figure 5. Summary of woundfin catch rates (*ln*+1) and number captured (n=) during fall population response station monitoring at the following stations: Above Washington Fields Diversion (AWFD), Quail Creek (QC), and Ash/La Verkin (AL), 2003 to 2015.

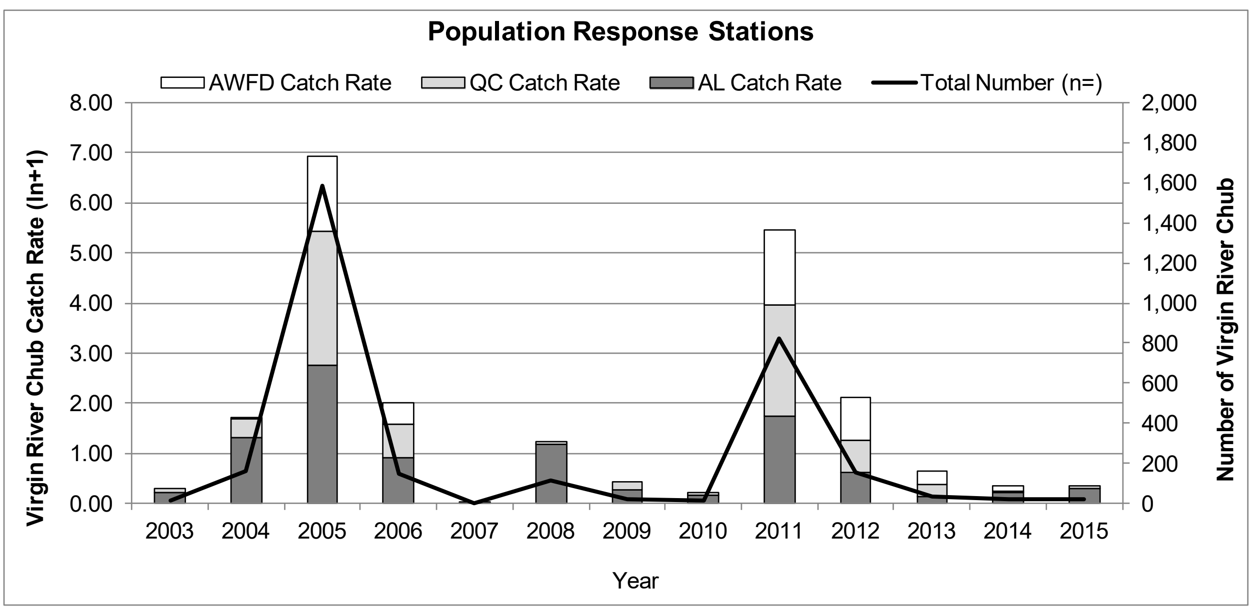

Figure 6. Summary of Virgin River chub catch rates (*ln*+1) and number captured (n=) during fall population response station monitoring at the following stations: Above Washington Fields Diversion (AWFD), Quail Creek (QC), and Ash/La Verkin (AL), 2003 to 2015.

The increased catch rates of woundfin in 2011, 2014, and 2015 also suggests the increase is the result of reproduction from stocked woundfin. All PRS stations were monitored prior to fall stocking events, in addition, no stocked woundfin were captured past spring in these years during PRS monitoring (Bennion and Fridell 2012; Bennion and Fridell 2015). Huizinga and Fridell (2012) provide a full analysis of PRS station data (2003 to 2010).

Full Pass Distribution Monitoring

Intensive fish distribution surveys (full pass distribution) between La Verkin Springs and the WFD were initiated in 2002 in response to the colonization of red shiner above the WFD (Fridell et al. 2003). Designated critical habitat for woundfin and Virgin River chub includes the Virgin River downstream of the river's confluence with Ash and La Verkin Creeks. However, fish also use the Virgin River between the confluence of Ash and La Verkin Creeks and La Verkin Hot Springs, as well as the lower portions of Ash and La Verkin Creeks. The full pass distribution surveys were extremely effective at providing native and nonnative fish distribution, population, size structure, and recruitment information. Even though red shiner were successfully eradicated above WFD in fall 2002, full pass distribution surveys were continued to identify other factors limiting native fish populations. Since 2003, these surveys are conducted biannually in spring and fall between La Verkin Springs and WFD. This is the most comprehensive population monitoring conducted on the upper Virgin River.

Full pass fish distribution surveys of the Virgin River between La Verkin Springs and the WFD are conducted in spring (March/April) and fall (September/October). All available habitats are sampled moving downstream, and seine hauls cover an average 50 square meters (538 square feet) of habitat. All fish are enumerated into adult and young age classes based on size. A complete description of full pass distribution monitoring is described in Fridell et al. (2004) and Fridell and Morvilius (2005a). In addition, a full analysis of full pass distribution data (2002 to 2010) can be found in Huizinga and Fridell (2012).

A summary of woundfin and Virgin River chub numbers and catch rates for fall full pass (2003 to 2015) is provided in Appendix C. Within this 13-year dataset, there is a clear correlation between high water years and a woundfin and Virgin River chub positive response (Figures 7 and 8). The increased catch rates for both species during 2005 and 2011, are caused in part, by a large reproductive event following high spring flows (Fridell

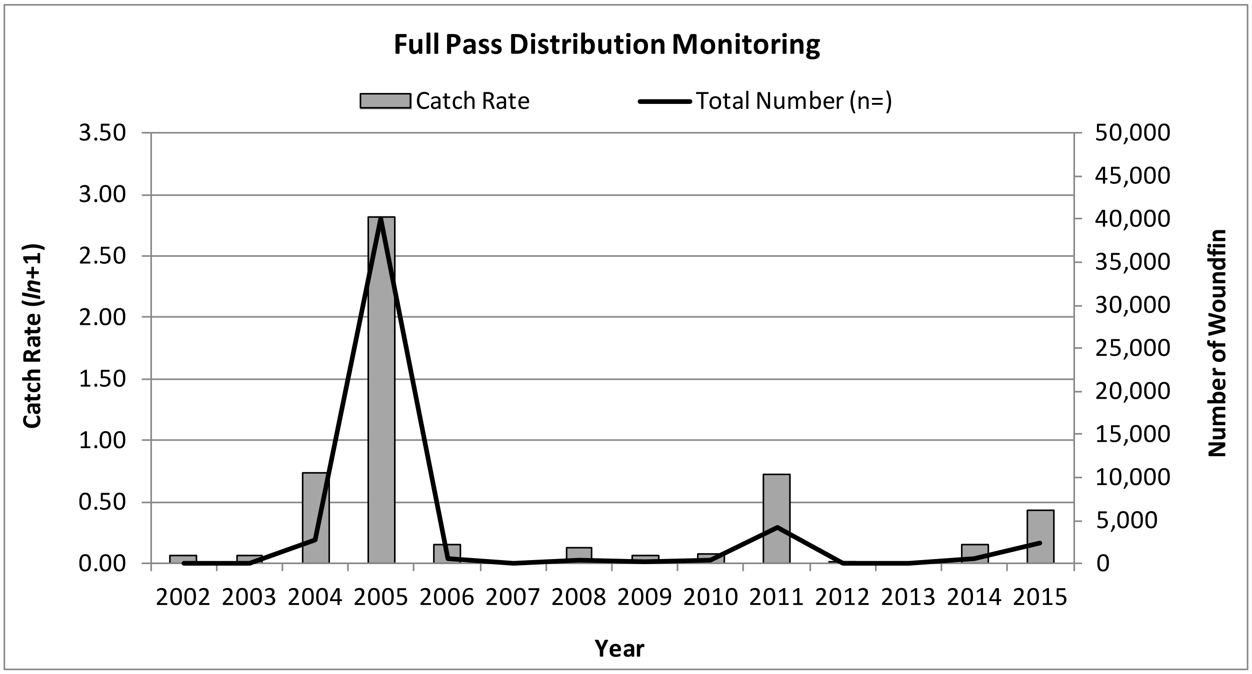

Figure 7. Summary of woundfin captured (n=) and catch rate (*ln*+1) during fall full pass distribution monitoring, 2002 to 2015.

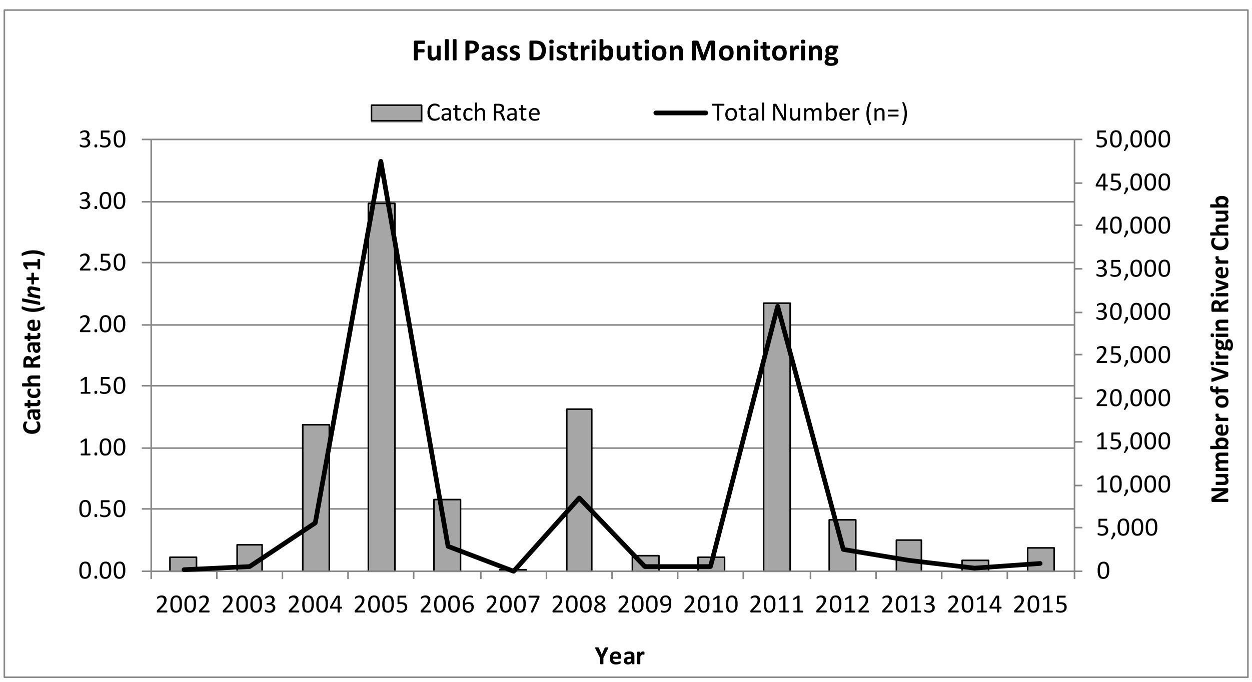

Figure 8. Summary of Virgin River chub captured (n=) and catch rate (*ln*+1) during fall full pass distribution monitoring, 2002 to 2015.

and Morvilius 2005a and 2005b). The low capture rates seen in 2003 and 2007 correlate to water quality issues associated with distinct high flow events (see section 2.3.3.1). A water quality event in 2007 resulted in a fish kill and wild woundfin were essentially extirpated throughout their critical habitat in Utah (USFWS 2008a; Huizinga and Fridell 2012). This same event also resulted in low numbers of Virgin River chub being captured (Figure 8, Appendix C). In 2008, captures of woundfin and Virgin River chub were the result of stocking efforts (see section 2.3.3.5), with the first wild woundfin captured in June (i.e., reproduction from stocked woundfin) (Fridell and Bennion 2019). The increase in catch rates for woundfin in 2014 and 2015 are likely a result of reproduction of stocked woundfin (see section 2.3.3.5). During 2014 and 2015, a majority of the woundfin captured in spring were stocked (100 percent and 55 percent, respectively), but in the fall, the majority of woundfin captured were wild (97 percent and 99.9 percent) Fridell and Bennion 2019).

Overall, 2005 and 2011 were higher population years for woundfin and Virgin River chub, with the increased catch rates driven by young fish. Following these years, catch rates were very low and adults comprised the majority of fish captured (Fridell and Bennion 2019). Since catch rates correspond with water years, catch rates in 2015 were expected to remain low due to the lack of spring runoff; however, catch rates more than doubled those of 2014 for both woundfin and Virgin River chub (Figures 7 and 8, Appendix C). While the increased catch rates for woundfin can be attributed to stocking efforts, this is not the case for Virgin River chub, which were last stocked in 2013 (see section 2.3.3.5). In addition, young Virgin River chub comprised 62 percent of the total Virgin River chub captured during 2015 fall full pass (Fridell and Bennion 2019).

Virgin River Chub Hoop Net Monitoring

In 2004, the VRP contracted BIO-WEST Inc. to evaluate monitoring methods for Virgin River chub and begin development of a long-term monitoring plan. The results of this effort, along with an examination of historical data, showed that while seining may be an appropriate method for tracking trends in the abundance of young Virgin River chub, it is not an effective method for collecting individuals larger than 150 mm (Golden and Holden 2005). Instead, collection efforts with multiple gear types indicated that hoop netting was the most effective method for catching large adult Virgin River chub.

In 2005, the VRP funded UDWR to continue attempts to track the abundance of all size classes of Virgin River chub, and to conduct a pilot study in 2006 to establish a long term Virgin River chub monitoring project using hoop nets (Golden and Fridell 2008a). The pilot project established five monitoring stations between La Verkin Springs and the

WFD. The five stations included: Above Ash/La Verkin, Above Gould's Wash, Above Quail Creek, Above Hurricane Bridge, and Above WFD (Figure 9). These locations were selected because they contained sufficient Virgin River chub habitat (e.g. pools, deep runs, eddies) and were representative of the different geomorphic reaches above WFD (Fridell et al. 2003).

The hoop net monitoring design and protocol proved adequate for evaluating the relative abundance of Virgin River chub in the La Verkin Springs to WFD reach. Since then, it has been implemented annually to provide a baseline data set and quantify annual variation in relative abundance among stations and years (Golden and Fridell 2008b; Golden and Fridell 2009; Dobbs and Fridell 2010).

Virgin River chub hoop net monitoring is conducted annually during October or November, dependent on flow and temperature conditions. Prior to monitoring, maps of all hydrologic habitats are developed within each station, following methods similar to those used for population response stations (Bennion and Fridell 2006). Habitat mapping is used for Virgin River chub monitoring to: 1) ensure an adequate amount of habitat was available for setting 15 hoop nets in each station; and 2) provide a measure of habitat availability against which to compare annual habitat changes within each station.

Fish monitoring is conducted within each station using 15 hoop nets set in areas representing, and containing relatively high availability of Virgin River chub habitat. Hoop nets are set in mid-afternoon, allowed to fish overnight, and collected the following morning. All species are enumerated and measured. Catch rates are calculated by dividing the total number of Virgin River Chub captured by the number of trap hours (i.e., number of hours that a given trap was available to fish). A summary of Virgin River chub monitoring (2006 to 2010) is provided in Huizinga et al. (2011).

To examine Virgin River chub trends in this dataset, the five original stations were pooled by year (i.e., the total number of Virgin River chub captured divided by the total trap hours by year). A summary of this data set, including numbers and catch rates for Virgin River chub monitoring from 2003 to 2015, is provided in Appendix D.

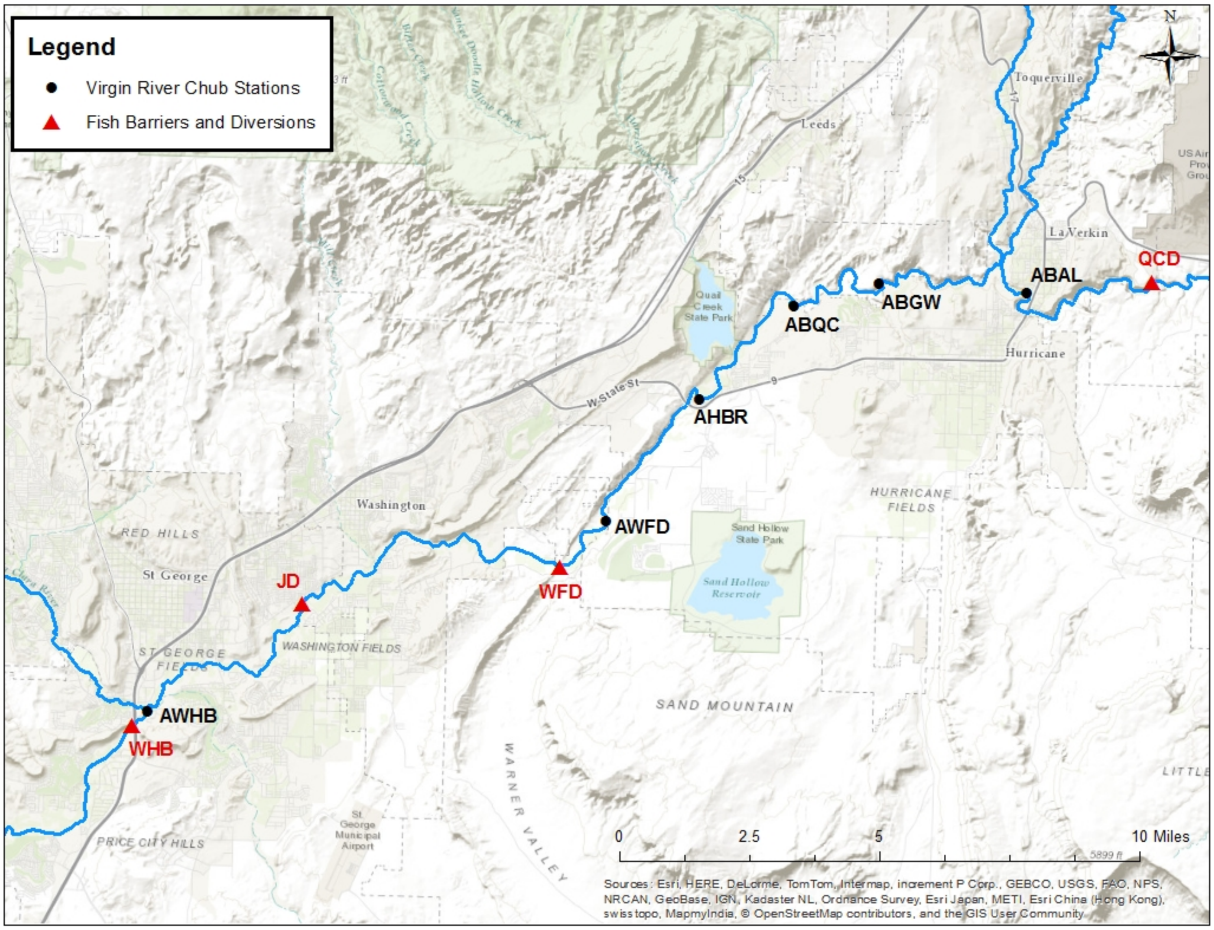

Figure 9. Virgin River Chub Stations in the upper Virgin River basin. Map includes the Above Ash – La Verkin (ABAL), Above Gould's Wash (AGW), Above-Below Quail Creek (ABQC), Above Hurricane Bridge (AHBR), Above Washington Fields Diversion (AWFD), and Above Webb Hill Barrier (AWHB) stations. Note: Quail Creek Diversion (QCD), Washington Fields Diversion (WFD), and Johnson Diversion (JD); Webb Hill Barrier (WHB) is also included for reference; however, it no longer exists (i.e., sedimentation following high flows in December 2010)

The overall trends of Virgin River chub captured during Virgin River chub hoop net monitoring are similar to the trends seen in full pass distribution and PRS monitoring via seine, but at a lesser scale (Figure 10). This decrease of magnitude is likely due to the difference in age classes represented by monitoring method (i.e., smaller/younger fish captured with seining, verses larger/adult fish captured with hoop-nets). A good example of this can be seen when comparing trends in Virgin River chub monitoring with trends in Recovery Team data for Virgin River chub at the Near Ash Creek station (Figure 11, Appendix D and E). Trends are very similar; however, the peaks in Recovery Team data are likely being driven by captures of young Virgin River chub.

Virgin River chub populations continue to fluctuate with increases in abundance correlating with above average water years. Catch rates during 2005 and 2011 are largely caused by a large reproductive event following high spring flows (Fridell and Morvilius 2005a; Golden and Fridell 2008a). As with all native fish species above WFD, Virgin River chub populations increased in 2005 and 2011 and dropped during the following low water years. Since 2007, variation in catch rates mimic the general pattern of Virgin River chub relative abundance, where the population shows slight increases followed by declines (Figure 10). Given annual fluctuations over the past 10 years, Virgin River chub monitoring data indicate that a small adult population continues to persist and when conditions are favorable, Virgin River chub are able to reproduce and recruit into the population.

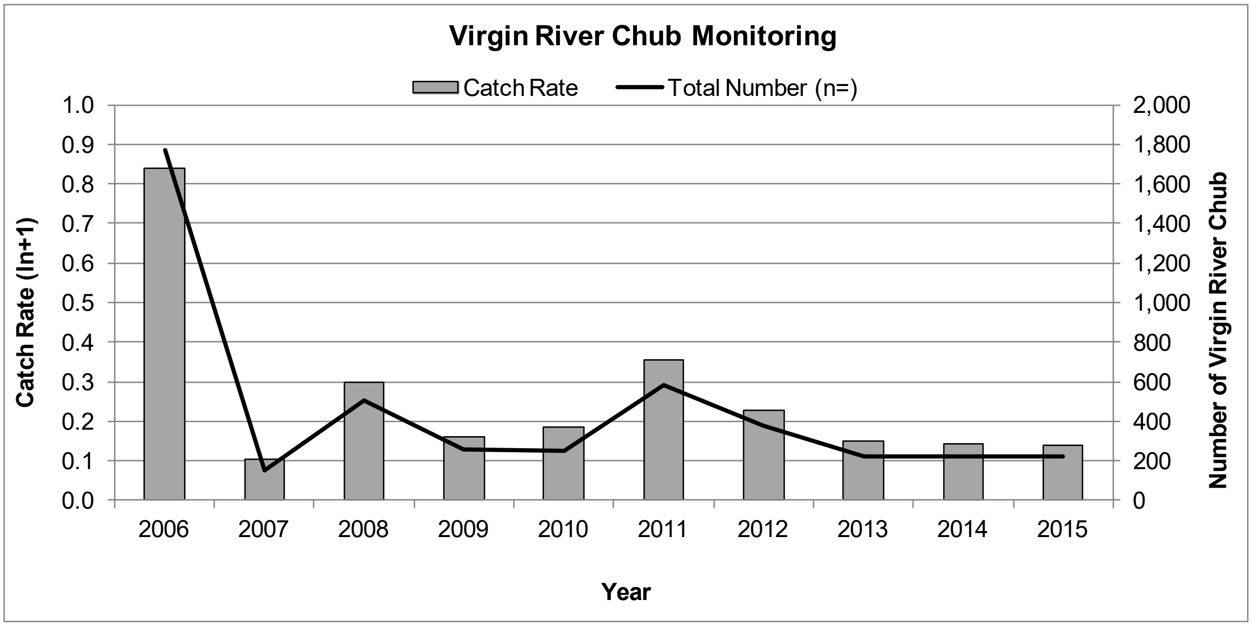

Figure 10. Virgin River chub catch rate (*ln*+1) and number of Virgin River chub captured (n=) during fall hoop net monitoring at the following stations: Above Ash/La Verkin, Above Gould's Wash, Above Quail Creek, Above Hurricane Bridge, and Above Washington Fields Diversion, 2006 to 2015. Note: stations were combined for this data set.

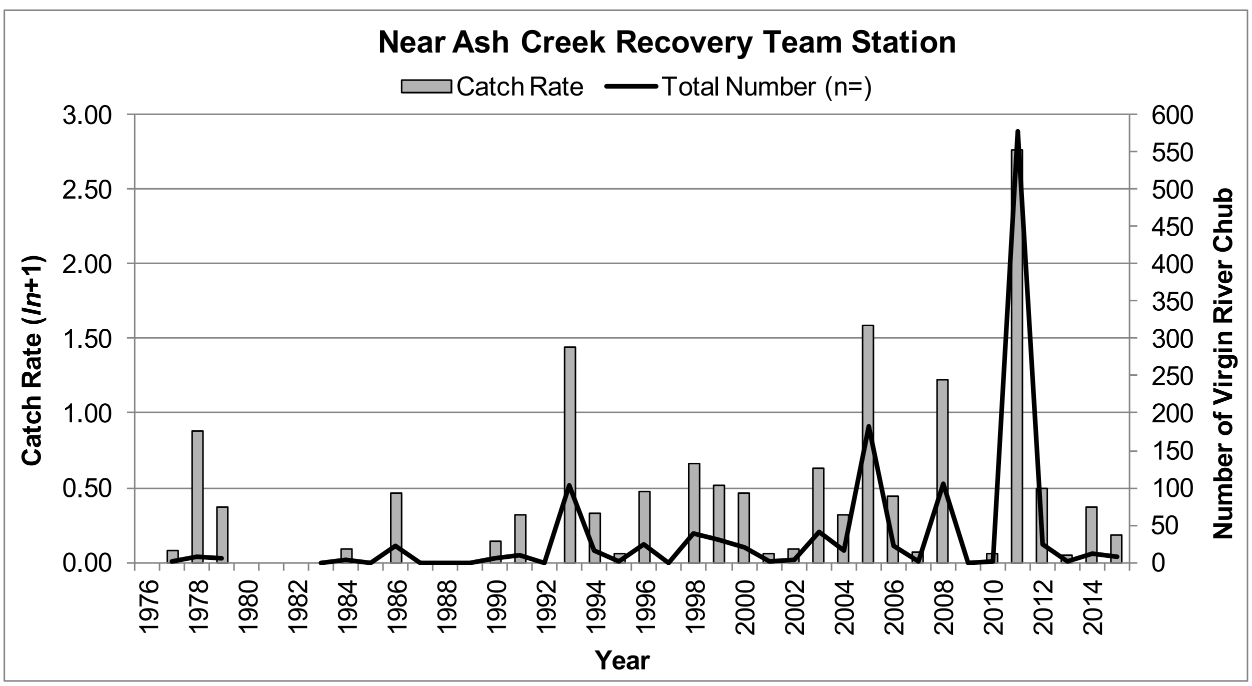

Figure 11. Virgin River chub catch rate (*ln*+1) and number captured by year for the Near Ash Creek Recovery Team Station, 1976 to 2015. Note: no monitoring occurred in 1976, 1980, 1981, and 1982.

WFD to Lake Mead:

Recovery Team Monitoring

The most complete description of Recovery Team monitoring and data is summarized in Holden et al. (2001). Between 1978 and 2015, woundfin relative abundance trends are very similar among the Twin Bridges and Beaver Dam Wash stations (Figures 12 and 13, Appendix F and G). At Beaver Dam Wash, the highest catch rates were in 1978 and 1979, while at Twin Bridges the highest years were in 1980 and 1982. While catch rates correlate with water years, including peaks during high water years (1978 to 1980) and declines in low water years, declining catch rates in subsequent years also correlates with red shiner colonization at both stations. Aside from a few captures in the 2000s, woundfin have essentially been absent from Beaver Dam Wash and Twin Bridges since 1988 due to red shiner colonization. While red shiner were extirpated from WFD to the Stateline Barrier (including the reach of river containing the Twin Bridges Recovery Team station) in 2011, woundfin are rarely caught at the Twin Bridges station, likely due to the impacts from low instream flows and high water temperatures in this stretch of the river.

Virgin River chub continue to occupy pool habitats in the Twin Bridges area. However, the recovery team monitoring occurs in run habitats preferred by woundfin instead of the pool habitats preferred by Virgin River chub. Therefore, catch rates of Virgin River chub through Recovery Team Monitoring at Twin Bridges does not adequately represent chub abundance in this stretch of the river.

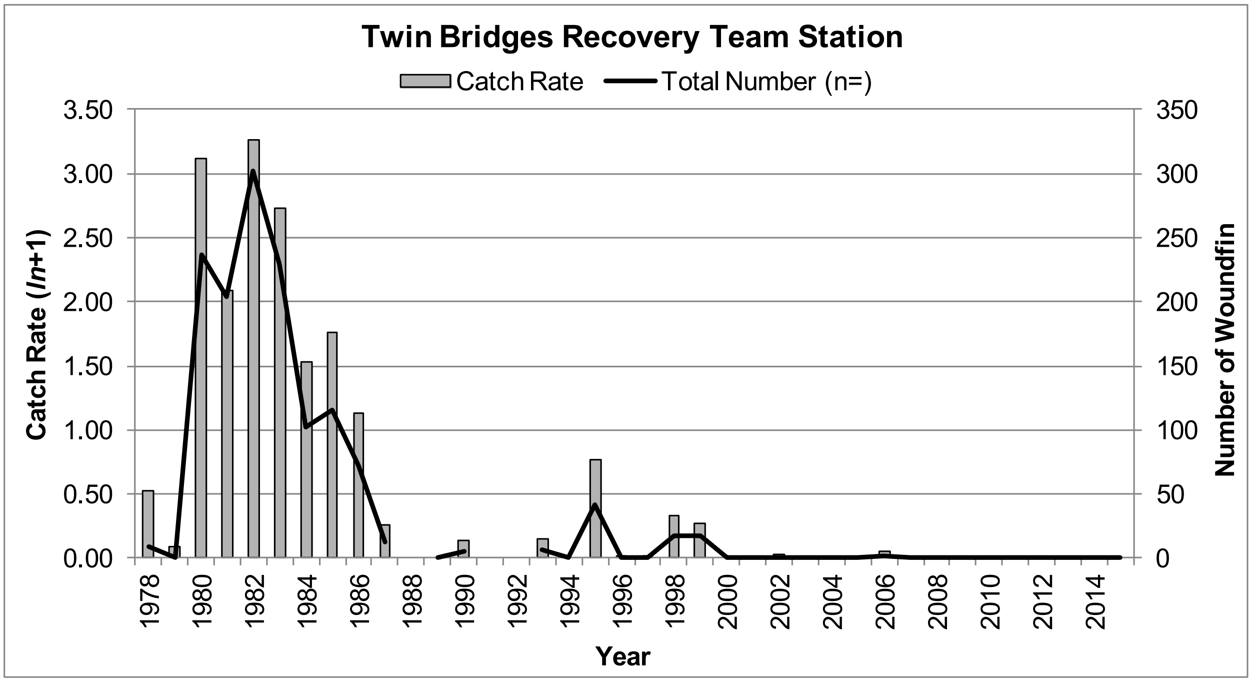

Figure 12. Woundfin catch rate (*ln*+1) and number captured by year for the Twin Bridges Recovery Team Station, 1978 to 2015. Note: no monitoring occurred in 1988, 1991, and 1992.

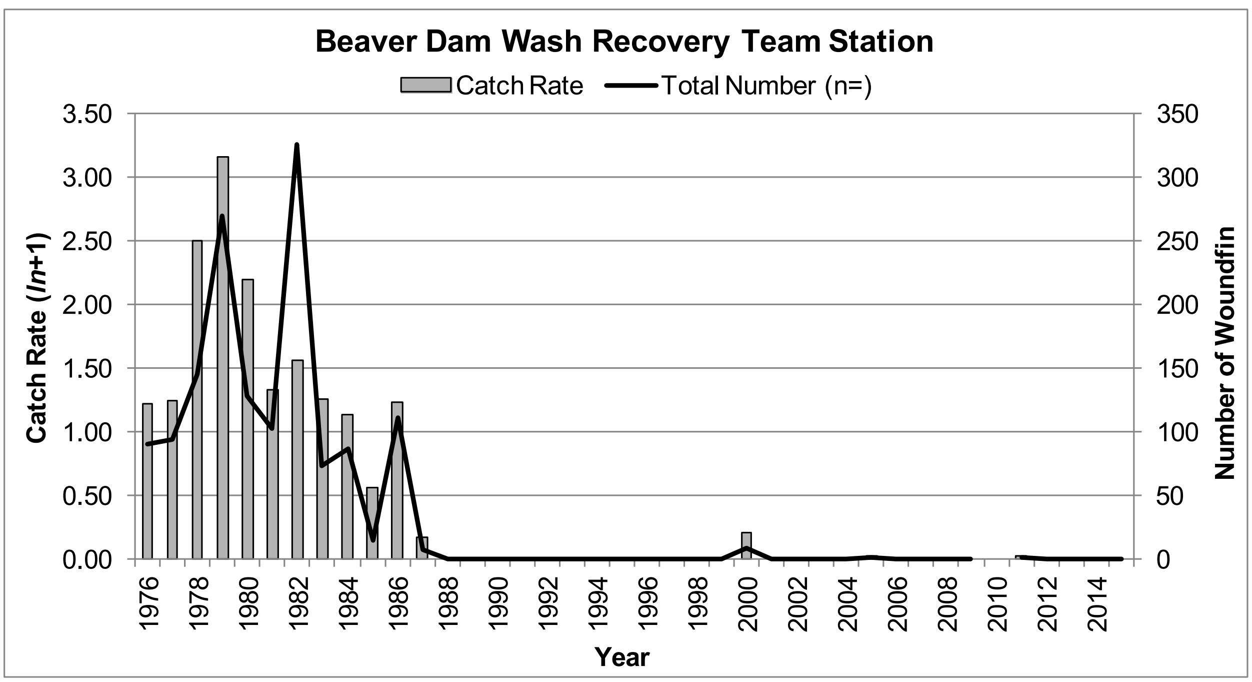

Figure 13. Woundfin catch rate (*ln* +1) and number captured by year for the Beaver Dam Wash Recovery Team Station, 1976 to 2015. Note: no monitoring occurred in 2010, fall 1997, and fall 2014; substituted with Riverside station for fall 1997 and Mesquite Diversion station for fall 2014.

Beginning in the lower Virgin River Gorge near Littlefield, Arizona, a series of springs restores baseflow as far downstream as the Bunkerville Diversion. Pre-development, these spring flows augmented flow from the upper river. Today, baseflows in this reach of river are sufficient to support a resident fish population, but are likely limiting those populations at some unquantified level (Albrecht et al. 2007).

Holden et al. 2001 documented a precipitous decline in woundfin abundance at the Beaver Dam Wash station beginning in the mid-1980s. By 1988, woundfin were no longer collected at this recovery team monitoring site (Figure 12). Despite low numbers of woundfin in Beaver Dam Wash monitoring in 1996 and 1997, naturally produced woundfin have remained largely absent from collections through 2006 (Holden and Abate 1999, Albrecht et al. 2007).

The Virgin River near the Beaver Dam Wash station constitutes the second core area for Virgin River chub. Virgin River chub occurred at the Beaver Dam station every year from 1996 through 2005 (Golden and Holden 2004, Albrecht et al. 2007). The abundance of Virgin River chub at Beaver Dam Wash declined through the late 1990s into the year 2000 (Figure 14). A peak in Virgin River chub reproductive success occurred in spring 2002 (Golden and Holden 2004). However, by fall, abundances of young of the year had declined to more typical levels (Figure 14).

During the high flows in 2005, Virgin River chub appeared to benefit more than other native species, but again abundances of young of the year in the fall declined to more normal levels (Albrecht et al. 2007). In 2004, a multiple pass, mark recapture population estimate was conducted throughout a 0.8 km (0.5 mi) stretch of river just upstream from Beaver Dam Wash. Results of that effort estimated the size of the Virgin River chub (>150 mm) population to be 369 (95% confidence interval: 214-449); the recapture rate of marked smaller chub was too low to generate an estimate.

The density of Virgin River chub at Beaver Dam Wash was approximately 10 percent of that estimated at the core area near the Ash Creek Recovery Team station in Utah (Golden and Holden 2005). Since 2007, Virgin River chub numbers near Beaver Dam Wash have largely increased since the low numbers of the late 1990’s and early 2000’s. Virgin River chub capture rates have increased significantly and in certain years, have shown historically high catch rates and abundance. In those years, much of the catch rates and abundance can be attributed to successful reproduction and most of the Virgin River chub captured are young-of-year fish. However, the effects of nonnative fish predation and competition are evident in the significant drops in catch rates and abundance in the years following successful reproduction.

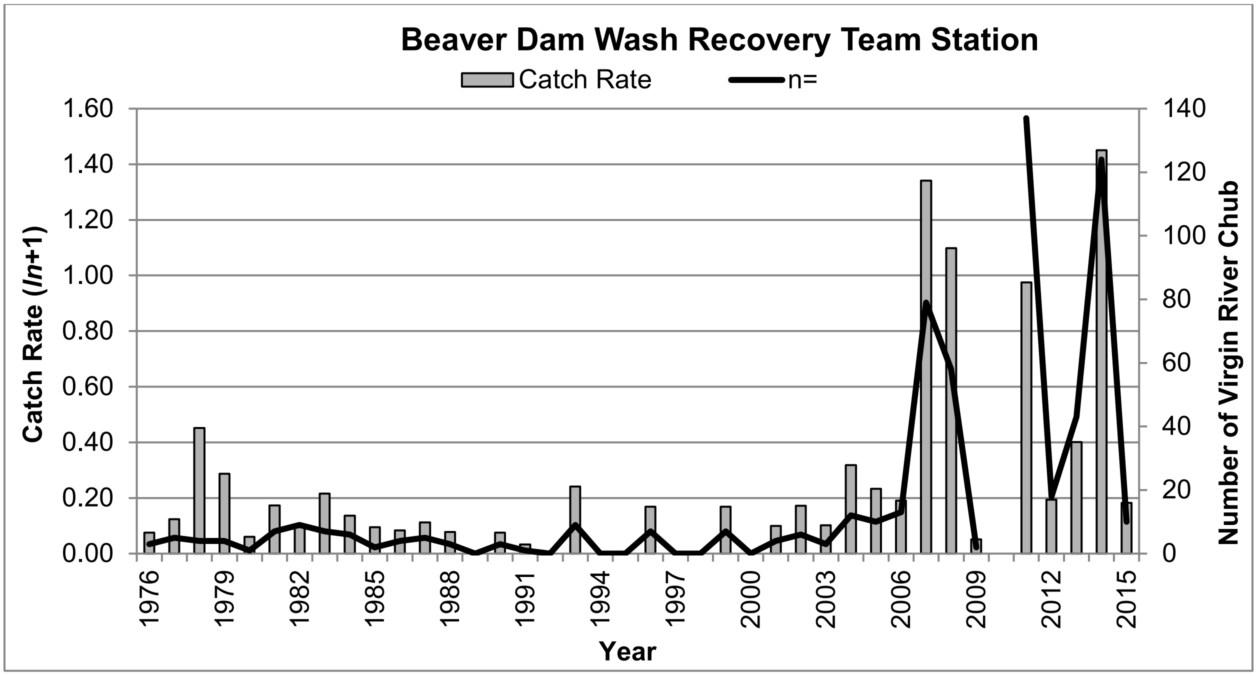

Figure 14. Virgin River chub catch rate (*ln* +1) and number captured by year for the Beaver Dam Wash Recovery Team Station, 1976 to 2015. Note: no monitoring occurred in 2010, fall 1997, and fall 2014; substituted with Riverside station for fall 1997 and Mesquite Diversion station for fall 2014.

The river near Beaver Dam Wash is characterized by a relatively high percentage of riffle and pool habitats, preferred by Virgin River chub (see section 2.3.1.1). The Virgin River downstream of Beaver Dam Wash is comprised of more run type habitats, which are less preferred by Virgin River chub (see section 2.3.1.1). Presumably, due to these habitat differences, Virgin River chub have always been much less abundant in the lowest portions of the Virgin River (Mesquite and Riverside reaches) and have been absent in most years.

2.3.2. Management and conservation efforts in the Virgin River Basin

2.3.2.1 Virgin River hydrology, history of water use, and sediment management

River Hydrology

The Virgin River is a desert stream located in southwest Utah, northwest Arizona, and southern Nevada. The Virgin River originates in the high plateaus north of Zion National Park and derives a large portion of its annual flow from high elevation snowmelt (WCWCD 2007). However, spring sources, groundwater discharges and ephemeral tributaries also contribute to the water supply in the river. The river flows off of the high plateaus in a southwest direction for approximately 162 miles before the rivers empties into the Colorado River at Lake Mead. The watershed is largely composed of sand and bare rock and has a watershed area of 4,123 square miles (WCWCD 2007).

The river is characterized by consistent base flows throughout the year. The mean (average) flow at the St. George stream gauge is 182 cfs and the median flow is 96 cfs (USGS 2019). Flooding is not uncommon in the Virgin River. Large flood events are typically caused by winter storms and summer monsoonal events. Peak flows during flood events are relatively consistent, ranging between 5,000 to 15,000 cfs (WCWCD 2007). Between 1922 and 1966, larger flood events were primarily generated by summer and fall monsoon storms. Since 1967, major flood events have been generated by large winter frontal storms where warmer rain events quickly melt the existing winter snowpack in the basin (WCWCD 2007). Four of these winter floods have occurred since 1966 (1967, 1978, 2005, and 2010). A 1989 flood event was generated by failure of the Quail Creek Reservoir dam rather than natural storm events.

Upper Virgin River (Utah)

The flow of the Virgin River is affected by diversions throughout the basin. In general, water is taken out of the river at diversion structures and used for irrigation or human consumption, with any excess water bypassing the diversion. Water rights allow for a consumptive use of the water and unused water returns to the river at a location downstream from where it was diverted. This returned water helps meet the legal water right of the next diversion downstream. This process is repeated as water moves through the system, from the top of the watershed to the bottom.

Diversions are in place on the Virgin River from the Upper East Fork of the Virgin River downstream to the lower main stem of the Virgin River. Many of these have been in place and operated for decades. One of the first diversions in the upper Virgin River is in Zion National Park where water is diverted for use in Zion National Park's Watchman Campground area. Moving downstream, water is diverted by the Springdale Consolidated Irrigation Canal Company. Rockville Town Ditch has a diversion on the river that is shared with the Grafton Irrigation Company. The Virgin Irrigation Company, Virgin Canal Company, and Virgin Town have a diversion on the river. Historically, the Hurricane Canal Company had a diversion and the LaVerkin Canal Company had diversions built at the start of 20th century and just prior to the 20th century, respectively. The Quail Creek diversion replaced those two diversions in 1985. Farther downstream is the Washington Fields Diversion, which has the highest priority water right in Utah. The Johnson Diversion in St. George is the next diversion downstream. In Nevada, the Littlefield Diversion, the Mesquite Diversion, the Bunkerville Diversion, and the Riverside Diversion all remove water from the Virgin River. The following subsections provide an overview of these diversions and water management activities in the upper Virgin River system.

Virgin River Mainstem

In the late 1800s and early 1900s, diversions constructed upstream from the towns of Hurricane and La Verkin dry dammed the Virgin River. The Hurricane diversion and canal system was completed in 1904, and was located approximately 0.40 km (0.25 mi) below the present Quail Creek Diversion (QCD), with a year-round diversion right of 33 cubic feet per second (cfs) (Figure 15; WCWCD 1999). The system was extended to Bench Lake just south of Hurricane (also known as Hurricane Bench Reservoir) in the 1940s. With this extension, an additional 63 cfs of lower priority water rights was perfected. Therefore, when water was available, this diversion could take up to 96 cfs. Irrigation return flows from the Hurricane Canal Company generally flowed through Gould Wash or were dissipated at Bench Lake (Figure 15).

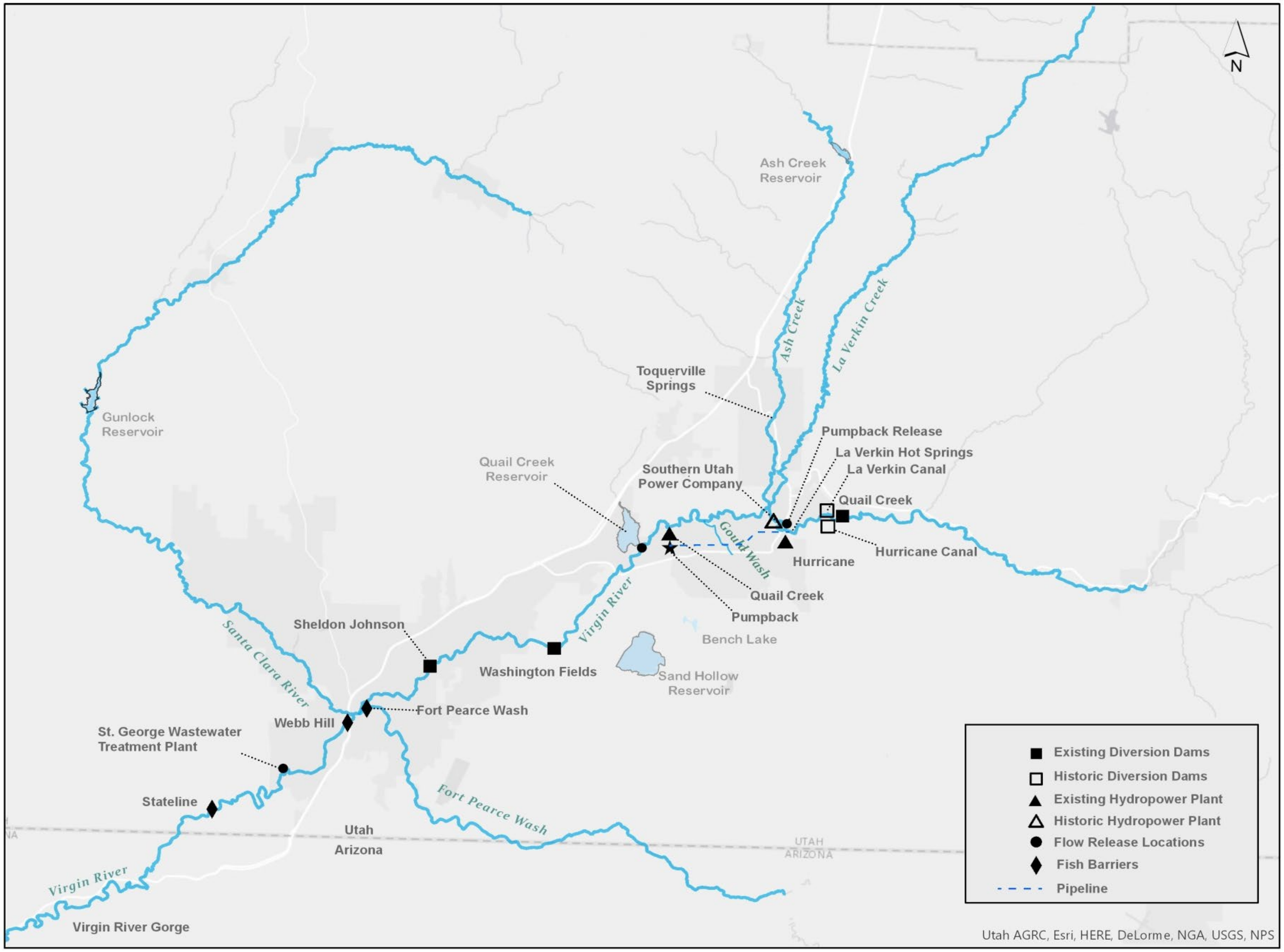

Figure 15. Location of diversions and inflows in the Virgin River between the Quail Creek Diversion and the Utah State line (Map provided by WCWCD).

The La Verkin diversion was completed in 1891, and was located about 1.21 km (0.75 mi) below the present QCD, with a year-round diversion right of 12 cfs (WCWCD 1999). Except during flooding, the La Verkin diversion dry-dammed the river downstream to La Verkin Springs during irrigation season (Figure 15). Irrigation return flows from the La Verkin diversion and canal flowed into La Verkin Creek and the Virgin River.

In the late 1920s, an additional non-consumptive water right was created with the construction of the Southern Utah Power Company hydropower plant. The La Verkin diversion and canal were enlarged to accommodate this use. The water was delivered through a pipeline from the canal to the power plant, which was located about 1.21 km (0.75 mi) below the bridge between Hurricane and La Verkin (Figure 15). Although the non-consumptive water right was for 100 cfs, only around 50 cfs was diverted for power generation, and then the water was returned to the river through the hydropower plant. This hydropower facility ceased operation in 1983. In 2007, the City of La Verkin acquired the La Verkin Bench Canal Company and the former shareholders now own share equivalents in the municipal secondary system.

There are two hydropower plants located on the upper Virgin River mainstem, the Hurricane Hydropower Plant located just upstream from the Hurricane-La Verkin bridge, and the Quail Creek Hydropower Plant located just above Quail Creek Reservoir (Figure 15; WCWCD 2019). The current Hurricane Hydropower Plant was constructed approximately 1.61 km (1.0 mi) upstream from the old location, extending fish habitat in this section. When the WCWCD is not storing water, any water remaining (after the water right for the Hurricane and La Verkin canal companies is met) flows through the Hurricane Hydropower Plant before returning to the river (WCWCD 2019). The Hurricane Hydropower Plant is designed to operate year-round at a capacity of 30 to 40 cfs. A portion of this water use represents the old Southern Utah Power Company non-consumptive water right. The Hurricane Hydropower Plant operates from flows already being diverted into the WCWCD system when the WCWCD is able to take water for storage during winter and spring.

During the early phases of irrigation management in the upper Virgin River, natural flow was considered to be the water remaining in the river after satisfying the Hurricane and La Verkin water rights, along with any additional discharge from La Verkin Springs, the Southern Utah Power Company hydropower plant return flow, tributaries, and return flow from irrigation. Occasionally, it was necessary to curtail junior water rights at diversions other than for the major agricultural users.

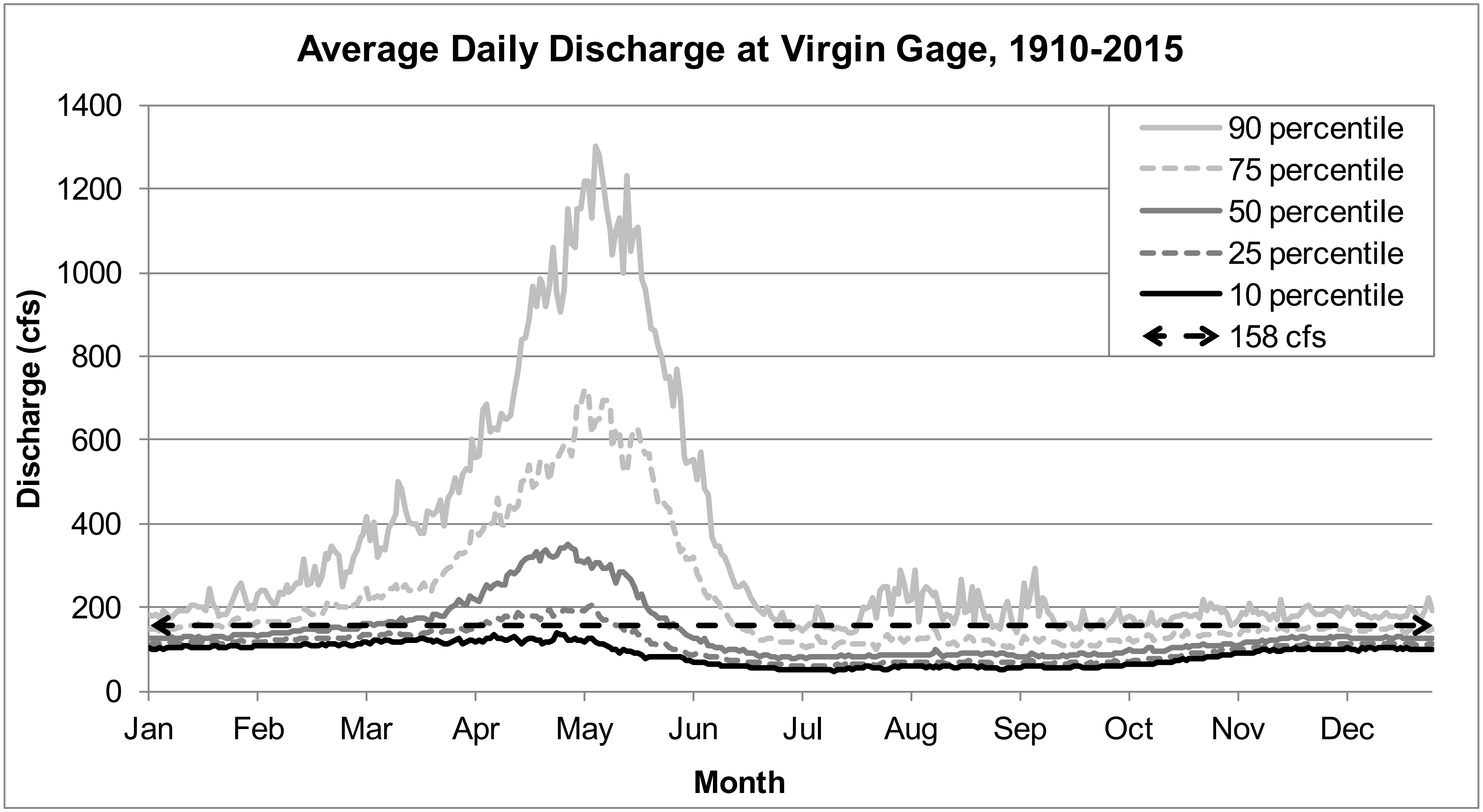

Figure 16. Average daily discharge in cubic feet per second (cfs) by percentile in the Virgin River at the USGS Virgin gage (#09406000), from January 1, 1910 to December 31, 2015. A percentile greater than 75 is considered above normal; a percentile between 25 and 75 is considered normal; and a percentile less than 25 is considered below normal. Note: the water right for the Hurricane and La Verkin diversions is also shown for reference (158 cfs).

The three major canal companies including La Verkin, Hurricane, and Washington Fields had pre-1900 water rights totaling 131 cfs and the lower priority Hurricane and La Verkin water rights along with the power plant water right totaled up to 158 cfs when water was available, of which up to 50 cfs was returned to the river (WCWCD 1999). Upstream from these historic structures (or present QCD) flow data for the Virgin River recorded (from 1910 to 2015) at the U.S. Geological Survey (USGS) Virgin gage (#09406000), showed that on an average year (50th percentile) the average daily discharge only exceeded 158 cfs for a short period from March to May (Figure 16). As a result of multiple diversions with water rights that often exceeded the natural daily discharge, flows in the upper Virgin River were segmented by these structures resulting in interspersed dry river reaches from the late 1890s to 1985.

Downstream from these diversions and La Verkin Springs, discharge in the Virgin River increased from irrigation return flows, springs, and tributaries along the river including Ash and La Verkin Creeks (Figure 15). These flows were captured further downstream at the WFD. The WFD was operated by the St. George and Washington Canal Company with a year-round water right of 86 cfs (WCWCD 1999). This water right shares an 1890 priority with the La Verkin and Hurricane irrigation water rights.

The WFD diversion was originally built in 1857, but after being washed out repeatedly by flooding, a new diversion was built in 1890 at a site approximately 4.83 km (3.00 mi) upstream from the original location(WCWCD 1999). Historically, the river was dry- dammed at this diversion. Currently, irrigation returns contribute additional flow downstream of this diversion structure. Approximately 10.30 km (6.40 mi) downstream of WFD is Johnson Diversion (Figure 15). In the section downstream of Johnson Diversion to the Virgin River Gorge, the Virgin River dried regularly prior to the development of the Quail Creek project (Gerner and Thiros 2014).

Water management operations on the mainstem Virgin River changed with the construction of the Quail Creek Project in 1985. This project, summarized in the section below, provided more flexibility in managing flows and other impacts, and, as a result, increased instream flows in the reaches downstream of the QCD.

Quail Creek Project

The WCWCD was created by court decree in 1962 to provide and manage water for Washington County. The Quail Creek Project was the WCWCD's first major water project (WCWCD 1999). This project included a diversion structure (QCD), pipeline, reservoir, and hydropower plants. The project replaced the La Verkin and Hurricane Canal diversions, delivering the water rights for both companies through the WCWCD system and the old diversions were abandoned.

The QCD was built in 1985 just upstream from the historical Hurricane and La Verkin diversions (Figure 15). The Quail Creek Project was designed to divert water to WCWCD storage facilities (e.g., Sand Hollow and Quail Creek Reservoirs) during the winter and spring when flows exceed the level needed to meet pre-1900 water rights (WCWCD 1999). When flows drop to the point where all water is needed to meet the pre-1900 water rights (generally by June), no excess water is available and no diversions are made for WCWCD storage. The Quail Creek pipeline is designed to divert up to 250 cfs from the QCD for delivery to WCWCD storage facilities, but generally takes less water due to operational factors (WCWCD 1999). Any water in excess of the available 250 cfs capacity may bypass the QCD diversion and flow downstream.

With the exception of flood events, base flow in the river rarely exceeds the level of pre-1900 water rights. When water exceeds these levels, it generally cannot be delivered to the Quail Creek pipeline. Water during high flow or storm events may be rejected because the debris create hazards to the diversion structure and the silty water is unsuitable for irrigation or reservoir storage. Therefore, if water quality is compromised by silt and debris (i.e., during summer floods or high flow events) the water may bypass the QCD and flow downstream. Regardless of base flow, current operations maintain a minimum bypass flow of 3 cfs at the QCD pursuant to the Virgin Spinedace Conservation Agreement and Strategy (VSCAS) (Lentsch et al. 1995).

The Quail Creek Project diverts the same water rights that have been in place since the turn of the 20th century. Therefore, the Quail Creek Project did not change summer stream flow conditions in downstream reaches (with the exception of the 3 cfs bypass for Virgin spinedace). In addition, the Quail Creek Project restored population maintenance flows further downstream when the Hurricane Hydropower Plant replaced the old power plant (WCWCD 1999). Additional water has also become available with the piping of La Verkin, parts of Hurricane, and Washington Fields irrigation systems. When irrigators cut back on water use (i.e., piping leads to increased efficiency), more water is available at the head of the system. Additional water may become available at the QCD or the Hurricane Hydropower Plant as the remaining open ditches are converted to pipelines in the Hurricane canal system. Downstream from the QCD, river flows increase with the addition of water from La Verkin Springs, Ash Creek, La Verkin Creek, other minor springs, and agricultural return flows (WCWCD 1999).

The Quail Creek Project continues to honor the pre-1900 water rights of the three canal companies (131 cfs), in particular avoiding diversions that would reduce flows below the 86 cfs water right or natural flow (whichever is less) as measured at the WFD (WCWCD 1999). Before construction of the Quail Creek Project, when summer flows were low, there was no flow "supplementation" used to provide 86 cfs at the WFD. Once the Quail Creek Project began operation, water could be released from storage to contribute to these flows under certain conditions.

Additional improvements that WCWCD has made to certain facilities has also benefited native fish. In June 2005, a fish screen was constructed at the WFD. Prior to the construction of the fish screen, the diversion of water into the Washington Fields Canal system entrained native fish. The diversion of water into the WFD also occasionally dewatered portions of the Virgin River in the reach below the WFD from mid-June through early September. The fish screen bypasses fish into the river downstream of the diversion structure, thereby preventing fish from entering the pipe that carries irrigation water to farms in the area. Currently, the amount of water necessary to maintain operation of the fish screen (1 – 3 cfs) is returned to the river below the WFD. Bypass flows in this reach offer the first opportunity to prevent the loss of native fish populations from reaches upstream of the WFD. The fish screen also provides a mechanism to provide a small amount of water for instream flows downstream of the structure.

Beginning in 2010, the VRP and WCWCD began work on a pumpback system to augment river flow in the reach below the Hurricane Hydropower Plant in order to mitigate high water temperature conditions during summer months (Figure 15). The pumpback system was completed in 2012 and is used to augment river flows in the reach between the hydroplant and WFD. Although the pumpback is designed to release up to 28 cfs, depending on reservoir elevation and other factors, the maximum release between 2012 to 2015 has ranged from 18.3 to 24.8 cfs (Bennion 2015). The pumpback system is comprised of two natural gas powered pumps that can offset user demand from the river, by delivering stored water from the Water District at Sand Hollow Reservoir to Hurricane irrigators. Therefore, during summer months when the pumpback system is operating, more water is available for release at the Hurricane Hydropower Plant.

Some instream flows are also provided through various municipal operations. Water from the Quail Creek Project that is used in municipal systems is treated at the City of St. George Wastewater Treatment Plant near Bloomington (Figure 15). Treated water is reused in Washington County's secondary water system, and is primarily used to irrigate parks, cemeteries, and golf courses. The Wastewater Treatment Plant releases a minimum of 3 cfs in accordance with a requirement between the State of

Utah and the City of St. George. Additional water released from the plant helps supplement summer base flows and results in more frequent surface flow through the Virgin River Gorge. However, the river still dries up during low discharge periods as the reach in the Virgin River Gorge has historically consisted of intermittent segments of dry streambeds and/or standing pools during summer months (Addley and Hardy 1998).

Virgin River Turbidity

Turbidity in the Virgin River can vary widely (Hilmes and Vaill 1997). Because the watershed consists mostly of fine sands, clay, and rock, the Virgin River streambed is mostly sand, cobble, and clay. Within the average range of flows, water in the Virgin River has a high level of suspended sediment and is considered turbid (Hilmes and Vaill 1997). During precipitation events, turbidity increases and as the precipitation event ends, turbidity slowly decreases to a normal state of suspended sediment (Hilmes and Vaill 1997). However, during extended low flow events, suspended sediment in the Virgin River falls out and the turbidity of the water decreases to a mostly clear state.

The turbidity of the Virgin River influences survival of Virgin River fishes. Turbid water increases woundfin activity, largely through lower critical summer water temperatures due to reduced sunlight penetration (USFWS 2008a). Turbid water also reduces predation risk by providing effective cover in the water (Fridell and Bennion 2019)

Sediment Management in the Virgin River

Sediment management in the Virgin River is influenced by structures within the river. These include diversions, fish barriers, and other hardened structures such as bridges and utilities in the floodplain. Diversions are designed to capture a portion of the river to be used based on water rights and historic use. This is generally accomplished by backing up water and diverting it into a ditch, canal, or pipe. Because the diversion backs water up, it creates a flatter upstream gradient and stream flow slows resulting in sediment deposition. Almost all diversions are designed with a sluice, which is a structure that allows the water to be drained from behind the diversion which flushes the accumulated sediment from the diversion and or the intake ditch or canal. The historic Hurricane and LaVerkin canal diversions were sluiced on a regular basis, often daily, to maintain the function of the structures. The Washington Fields Diversion and its intake structure are sluiced regularly, especially when floods occur. Release of sediment helps to maintain a sediment balance in the river.

The Virgin River Program has constructed fish barriers on the Virgin River in Bloomington, near the Utah/Arizona State line, and in the Virgin River Gorge. Installation of these barriers has enhanced upstream barrier function by increasing the redundancy of the Johnson Diversion and Washington Fields Diversion. The Program has also constructed a barrier on the lower end of Fort Pearce Wash. These barriers create a wall in the river, changing the stream gradient, and disrupting sediment transport.

Utilities and bridges can also create a hardened point in the stream, fixing the stream elevation and preventing downcutting in flood events. Other activities, such as floodplain hardening, may impact stream sediment transport by changing stream width conditions.

The Quail Creek Project was constructed in 1985 and replaced the Hurricane and LaVerkin Canal diversions with a more modern diversion and a pipeline to Quail Creek reservoir. In the Virgin River, annual suspended sediment loads are commonly greater than 4,000,000 metric tons (Hilmes and Vaill 1997). During floods, virtually all of the sediment bypasses the QCD. The diversion has two roller gates that lower the top gate and allows for the flood debris to pass over the diversion. However, during lower flow periods sediment builds up behind the diversion structure. Accumulating sediments behind the diversion eventually interferes with the water intake structures and must be removed or flushed downstream by “lifting” the gates; this process is called sluicing. Sluicing is accomplished when there is a large flood in the river. In 2003, sediment released under the wrong conditions resulted in severely depressed dissolved oxygen levels in the river (see section 2.3.3.1). During this sluicing event, native fish mortalities were observed in the reach between QCD and WFD (Fridell et al. 2004).

The WCWCD developed and implemented a sediment management plan to mitigate the negative impacts of sluicing on native fish recovery (Olsen 2004). A major component of the plan was to adaptively manage sediment releases and use the information learned to refine subsequent sluicing events. The District notifies the VRP of sediment releases so conditions can be monitored on the Virgin River to ensure dissolved oxygen levels do not approach lethal levels for the fish (Olsen 2004; Fridell and Bennion 2019). The UDWR provides downstream monitoring to the District and feedback on the sluicing operations. With implementation of the sediment management plan, in-river water quality conditions during sluicing events have improved since 2003 (Fridell and Bennion 2019), and there have been no fish mortalities attributed to sluicing.

In 2014 the WCWCD installed new gates on the QCD. The new gates have the capability to release water through two different fixed aperture outlets (one designed for 3 cfs and the other 15 cfs) within the lower roller gate. This is a way to reduce sediment buildup at the diversion intake and provide a simple and direct release of the 3 cfs. Moving the location of the water release resulted in turbid water flowing from the diversion to the stream, a great improvement from previous conditions of high water clarity. There have been occasions when the release gate has become plugged with sticks or debris and it has been necessary to very briefly raise the gates and flush the debris. This has been accomplished multiple times by WCWCD with success.

The Interim Sediment Management Plan suggested a "feedback loop process" to provide recommended management strategies, implement monitoring of releases and associated conditions, monitor water quality events, and revise strategies based on successful results. As new information becomes available, the interim plan will be revised into a more final, but still dynamic management plan. The WCWCD's Quail Creek diversion is the only structure on the river with a defined sediment management plan. The WFD also generally follows the Quail Creek diversion guidelines for sluicing operations. Sluicing will always be necessary to maintain operations at the QCD and other diversions on the river.

Other natural events occur in the watershed that may have negative effects on water quality. For example, the rising limb of large floods often has depressed dissolved oxygen concentrations (Fridell et al. 2004). In addition, runoff from recently burned areas typically contains massive amounts of ash, sediment, and debris, which may cause significant effects on water quality and habitat (Huizinga and Fridell 2012). Events like these, especially when occurring upstream of woundfin and Virgin River chub occupied habitat, will continue to be a concern for native fish recovery.

Santa Clara River

The Santa Clara River confluences with the Virgin River approximately 16.1 km (10 mi) downstream of the WFD (Figure 15). Flows in the Santa Clara River are highly variable with water rights and instream flows met by the management of Gunlock Reservoir, which is located approximately 25.7 km (16 mi) upstream of the confluence (Figure 15).

In 1995, the WCWCD entered into the VSCAS, which called for an instream release of 3 cfs to reestablish population maintenance flows in the Santa Clara River (Lentsch et al. 1995). In pursuing the instream flow, it became clear that water rights on the Santa Clara River, in particular the Shivwits Band of Paiute Indian water rights, needed to be settled. The settlement was concluded in 2001 after passage of the Shivwits Band of the Paiute Indian Tribe of Utah Water Rights Settlement Act in 2000 (114 Stat. 737). Pursuant to the Santa Clara Project Agreement, which established who gets to use Santa Clara River water and under what conditions, the WCWCD was able to construct the Gunlock-Santa Clara Pipeline, which replaced multiple diversions and open delivery ditches with enclosed pipelines. This agreement also allowed for the release of 3 cfs at the Gunlock Dam outlet. The VRP has leased 2 to 3 cfs of water allocated to the Shivwits under these agreements for additional instream flow on an annual basis to benefit Virgin spinedace recovery efforts.

Ash Creek

Ash Creek confluences with the Virgin River approximately 7.6 km (4.7 mi) downstream of the QCD and 3.2 km (2.0 mi) downstream from the La Verkin Springs (Figure 15). Historically, Ash Creek was dry from above Ash Creek Reservoir to Toquerville Springs except during extremely high hydrologic events (Heilwell et al. 2000). The reach between Ash Creek Reservoir downstream to the town of Toquerville is very unique to the Virgin River watershed. This reach of the creek is located at the base of the Hurricane Cliffs and the Hurricane Fault (a dominant geologic structure of the area). Surface flow in this reach of the creek quickly infiltrates the sediment resulting in a completely dry stream channel. Therefore, even prior to historic records, this reach of Ash Creek was likely completely dry with no surface flow, except in periods of elevated levels of snow melt or summer thunderstorms (Heilwell et al. 2000).

In the tributaries of Ash Creek, in particular Wet Sandy, Leap Creek, and South Ash Creek, diversions for irrigation use existed long before the 20^{th} century (Stantec 2015). Since the late 1850s, Ash Creek was dry dammed by diversions near Toquerville Springs for irrigation and municipal uses and the water continues to be used for those same purposes today. There are some small springs which discharge to Ash Creek at the north end of Toquerville. Additionally, Ash Creek Springs discharge into the creek farther downstream.

Municipalities with water rights to Ash Creek Springs routinely make use of the water to help meet their culinary demand. Therefore, under current management of water in Ash Creek, it routinely goes dry and provides little benefit to the Virgin River (Stantec 2015). In the extremely dry years of 2014 and 2015, lower priority water rights were curtailed in lower Ash Creek and other tributaries to the Virgin River in order to meet the senior water rights for Hurricane, La Verkin, and WFD. This provided a more consistent instream flow in lower Ash Creek during those years.

La Verkin Creek

La Verkin Creek joins the Virgin River just upstream of Ash Creek. Historically, the upper reach of La Verkin Creek was diverted into Meadow Hollow Reservoir and then by trans-mountain diversion into the Kanarraville area in the headwaters of Ash Creek (WCWCD 1999). This reservoir has since been acquired by the WCWCD and most of the water rights have been returned to the La Verkin Creek drainage.
The WCWCD exchanged water shares of the secondary system in the La Verkin secondary water system in return for the Wilson family water rights (VRP 2008) in order to remove a diversion which prevented fish passage. Secondary water was provided to the Wilson family by other means, the diversion was decommissioned, and upstream fish passage was established. These water rights are used for instream flow in La Verkin Creek and the Virgin River, and are available for diversion at the WFD. Lower priority water rights in this tributary have also been curtailed in years when the senior water rights at Hurricane, La Verkin, and WFD are not satisfied and have contributed to additional instream flows in La Verkin Creek in those years.

Lower Virgin River (Arizona and Nevada)

Archeological evidence supporting the use of streamflow for irrigation purposes in the lower Virgin River Valley may date back as early as 500 AD. The Anasazi Indians inhabited the lower Virgin River and Beaver Dam Wash area from approximately 500 AD to 1150 AD (Glancy and Van Denburgh 1969). Since the Anasazi practiced agriculture, it is likely that primitive development and use of streamflow for irrigation purposes occurred during this time or earlier.

By the early 1800s, Native Americans use of streamflow for farming crops (corn and pumpkins) was documented in the lower Virgin River Valley by early American explorers (Glancy and Van Denburgh 1969). By the 1860s, the diversion of springs and streams in these areas led to the creation of water right laws, with statutes based upon the doctrine of prior appropriation (Welden 2003).

During the late 1800s, agriculture was the basis for the economy of new settlements in the lower Virgin River Valley in Arizona (Beaver Dam and Littlefield) and Nevada (Mesquite and Bunkerville). Mormon pioneers began to settle the area in the late 1800s, and began diverting water from the Virgin River to irrigate their farms along the floodplain (Glancy and Van Denburgh 1969). Multiple diversions, ditches, and canals were built to support floodplain farming throughout the lower Virgin River in Arizona and Nevada.

Since the late 1800s, four main diversions have functioned within the lower Virgin River including Littlefield, Mesquite, Bunkerville, and Riverside (Figure 17, Table 1). All of these diversions were named after and served nearby settlements. The town of Littlefield, settled in 1875, irrigated over 100 acres using the Littlefield and Petrified Springs canals (WCWCD 1994). The Littlefield Diversion and Canal was built in the late 1800s and diverted water from springs in Beaver Dam Wash, while the Petrified Springs Canal diverted spring water from near the Virgin River (Glancy and Van Denburgh 1969). The Mesquite Diversion and Canal were built when the town was settled in 1880. This diversion, along with the associated dike and canal, diverted water off the mainstem Virgin River; all of these structures have been destroyed by floods and rebuilt several times during the past century (WCWCD 1994).

The Bunkerville Diversion was completed on the mainstem Virgin River in 1877 and, similar to the Mesquite Diversion, was destroyed by floods and rebuilt several times (WCWCD 1994). The Bunkerville Diversion conveyed water to the town, irrigating over 202 hectares (500 acres) by the early 1900s (WCWCD 1994). The Riverside Diversion is the furthest downstream mainstem diversion above Lake Mead (WCWCD 1994). Streamflow that passes the Riverside Diversion empties into the northern part of the Overton Arm of Lake Mead, approximately 40 kilometers (25 miles) downstream.

Altered flow, sediment, and temperature regimes in regulated rivers are factors responsible for reduced distribution and abundance of native aquatic biota throughout the Colorado River Basin (Ward and Stanford 1979; Petts 1984; Deacon 1988; Poff et al. 1997; Propst and Gido 2004). Historically, decreases in flows below major irrigation diversions on the Virgin River has resulted in the reduction or loss of available physical habitat due to complete dewatering during low flow periods (USFWS 1994). In the lower Virgin River, approximately 18,574 acre-feet per year (AFY) of water rights were allocated by 1922 (Glancy and Van Denburgh 1969). In 1927, the Nevada Supreme Court decreed these water rights to have a pre-1905 priority date (Virgin River Habitat Conservation Plan (VRHCRP) 2013, unpublished data). This ruling established priority for these water right holders.

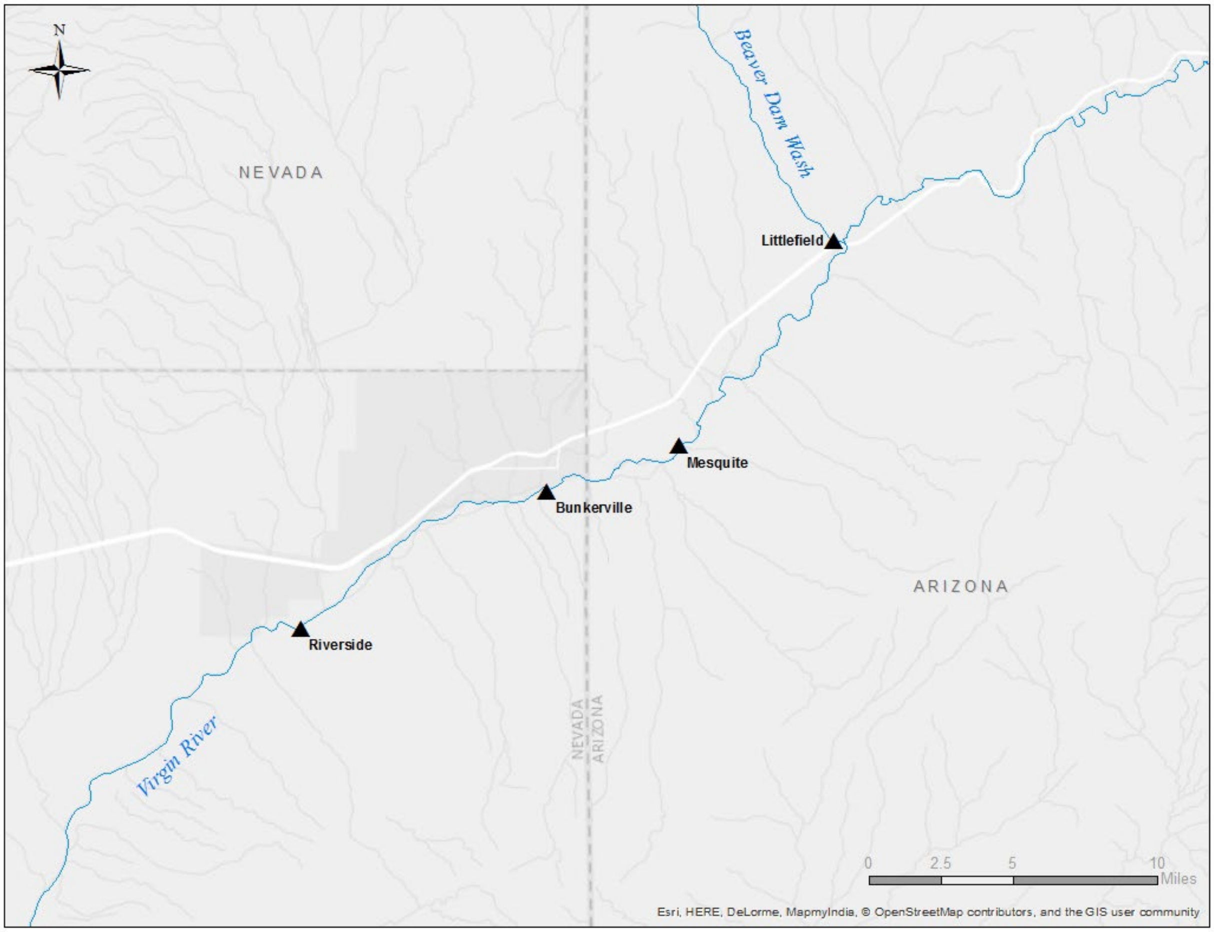

Figure 17. Location of main diversion structures in the lower Virgin River. The Littlefield Diversion is located on the Beaver Dam Wash in Arizona, and the remaining diversions (Mesquite, Bunkerville, and Riverside) are located on the mainstem Virgin River.

Table 1. Summary of diversion structures in the lower Virgin River and approximate amount surface water rights in acre-foot per year (AFY) by diversion structure. The Littlefield Diversion is located on the Beaver Dam Wash in Arizona, and the remaining diversions (Mesquite, Bunkerville, and Riverside) are located on the mainstem Virgin River.

Diversion	Approximate AFY[1]
Littlefield	650
Mesquite	12,014
Bunkerville	9,612
Riverside	2,888
Total	25,164

[1] One AFY equals 325,851 gallons

The use of surface water in the lower Virgin River has fluctuated over the years. In the Beaver Dam Wash and downstream reaches in Arizona, approximately 14,850 AFY was used for crop irrigation in the 1950s and 1960s (Glancy and Van Denburgh 1969). Between 1971 and 2000, surface water usage decreased, averaging 3,000 to 6,350 AFY. By 2005, as agricultural demands decreased, use declined to 1,650 AFY (ADWR 2009). In Nevada, approximately 31,591 AFY of surface water is owned or managed by one of the following agencies: Southern Nevada Water Authority (SNWA), Bunkerville Irrigation Company, or Mesquite Irrigation Company (VRHCRP 2013, unpublished data).

In 2007, the Bureau of Reclamation adopted the Colorado River Interim Guidelines for Lower Basin Shortages and coordinated Operations for Lake Powell and Lake Mead (Guidelines). The Guidelines provide a mechanism, called Intentionally Created Surplus, to encourage and account for augmentation and conservation of water supplies. Intentionally Created Surplus allows water users to fallow water rights in tributaries of the Colorado River with priority dates before 1929, and this water is then conveyed to the Colorado River for credit. For the lower Virgin River in Nevada, the Guidelines have enabled the SNWA to purchase and lease Virgin River surface water rights, and instead of using the water for agricultural use, allow the water to remain in the natural channel of the Virgin River to Lake Mead. In 2014, over half of the pre-1929 lower Virgin River surface water rights were utilized to create Intentionally Created Surplus (Johnson 2016).

To date, the diversion structures within the lower Virgin River divert surface water in the lower Virgin River. Therefore, while there may be an overall increase in instream flows from the Intentionally Created Surplus, flows within portions of the lower Virgin River are reduced or completely dewatered, even during critical summer periods (Senn 2016). In Nevada, a substantial portion of the water initially diverted returns to the Virgin River by way of sluicing activities or non-use return flows (e.g., agricultural runoff and ditch maintenance; Johnson 2016).

Although surface water provides the majority of irrigation in the lower Virgin River Valley, pumping of groundwater is also used to meet municipal, industrial, and agricultural needs in Arizona and Nevada. Prior to the 1960s this was largely an untapped source of water in the lower Virgin River (Glancy and Van Denburgh 1969). In the Arizona section of the lower Virgin River, groundwater use averaged 5,000 AFY between 1971 and 1975 (ADWR 2009). For the next 25 years groundwater use continued to rise, and by 2000 it averaged 9,150 AFY. By 2005, as agricultural demands began to decline, groundwater use decreased to an average of 2,950 AFY (ADWR 2009). As of 2005, there were 348 registered wells used for pumping groundwater in Arizona (ADWR 2009).

By comparison, in the lower Virgin River in Nevada, an estimated 2,800 AFY was pumped in 1968 (Glancy and Van Denburgh 1969). Within the Nevada section of the lower Virgin River, the Virgin Valley Water District (VVWD) is the major supplier of groundwater, with nine wells operating in 2010. Approximately 6,200 AFY of drinking water was pumped during 2014 and 2015, and groundwater is the only source of potable water purveyed by VVWD (Brown 2016). The VVWD considered applying for an ESA incidental take permit with the USFWS in order to extract up to 12,200 AFY through existing and future production wells (VRHCRP 2013, unpublished data). However, after a groundwater modeling study in 2012 (discussed in detail below) suggested there would be a very minimal reduction of Virgin River surface water flow from existing VVWD pumping, VVWD rescinded their request with the understanding that routine VVWD activities associated with facilities construction and operation are covered under the City of Mesquite's authorization since VVWD is considered a designated agent of the City (Kevin Brown, VVWD correspondence to USFWS, April 2015).

As agricultural water use continues to decline and population growth along the lower Virgin River increases, municipal and industrial water use is likely to increase as well. As such, demands for groundwater use will also increase as this is the only source of water for municipal and industrial use in the Virgin Valley area (VVWD 2012). The population within the lower Virgin River in Arizona increased from 99 in 1980 to 1,532 by 2000, and is projected to reach 3,267 by 2030 (ADWR 2009). The population growth in Mesquite, Nevada has outpaced national averages for decades, and has risen from 6,290 in 1995 to 20,173 in 2011, and is projected to reach 36,311 by 2050 (VVWD 2012). In Mesquite and Bunkerville (VVWD service area), the average annual use of groundwater between 2005 and 2011 was 5,632 acre-feet, and unless there is significant additional conservation measures, it is projected that 11,574 acre-feet of groundwater will be needed by 2050 (VVWD 2012).

Concerns were identified regarding the development of groundwater and the effects groundwater use could have on flows and water quality in the Virgin River (Glancy and Van Denburgh 1969). In 2003, a proposal to study surface flow was developed by USGS. In the USGS study, surface water flow measurements were conducted to evaluate Virgin River flows between the Virgin River Narrows and Lake Mead. The study indicated general trends in discharge, water temperature, and specific conductance seemed consistent with a river basin where surface water is diverted for agricultural and municipal purposes. Some of the diverted water is recycled back into the river through the shallow groundwater system downstream of the diversions (Beck and Wilson 2006).

In 2006, a Hydrologic Monitoring and Mitigation Plan (HMMP) was developed in accordance with a USFWS biological opinion required for land development in Mesquite, under the Mesquite Lands Act of 1986. The HHMP includes groundwater and surface water monitoring, with the goal to monitor the association between groundwater development and surface water (VRHCRP 2013, unpublished data).

An additional study was proposed to monitor the interaction between groundwater pumping, streamflow, and water quality within the mainstem Virgin River (USFWS 2008a; VRHCRP 2013, unpublished data). In 2012, a study was commissioned by the National Park Service (NPS), U.S. Bureau of Land Management (BLM), and USFWS to develop an accurate model to assist with predicting the effects of groundwater development on Federal water resources (Tetra Tech 2012). This study concluded that while the Virgin River is hydraulically connected to the Muddy Creek Formation, and groundwater is discharged by evapotranspiration between Bunkerville and Lake Mead, it is not discharging into the river at a rate high enough to increase baseflow within this reach (Tetra Tech 2012). The study concluded that while the primary source of groundwater production for culinary water and residential irrigation use in the lower Virgin River comes from the Muddy Creek Formation, existing groundwater pumping by VVWD may have little or no impact on flows in the Virgin River over the next millennium. However, it was noted that predictions on the effects of pumping should be used with caution, since the model was not calibrated to connectivity between surface and groundwater flows, and information regarding groundwater pumping and response were not available (Tetra Tech 2012). In addition, there is not a large gain or loss between the Virgin River and the aquifer based on previous USGS synoptic flow studies (Beck and Wilson 2006, Tetra Tech 2012).

Based on the current information available, the VVWD believes that there is no measurable hydrologic interface between the Muddy Creek aquifer and the Virgin River as the model predicted relatively minor effects to the surface flows of the Virgin River (Kevin Brown, VVWD correspondence to USFWS, April 2015; Bunker 2015). Therefore, VVWD does not believe that the pumping of groundwater or other activities have any impact or take on Virgin River species. Currently, the VVWD is not planning to request an incidental take permit from the USFWS, but plans to continue to assist with monitoring efforts associated with the HMMP (Kevin Brown, VVWD correspondence to USFWS, April 2015).

Although the study by Beck and Wilson (2006) and the model by Tetra Tech (2012) infer that groundwater pumping may have little or no impact on flows in the Virgin River, we have recommended monitoring efforts continue and are expanded in order to confirm the degree of connectivity between the aquifer and the river. Based on the uncertainty associated with the accuracy of the model, we recommended that the VVWD continue their involvement and support of the HMMP (Senn 2016). We are working with partners to coordinate recovery and conservation planning for the lower Virgin River to help minimize and mitigate for impacts from urban development through a Memorandum of Agreement for lower Virgin River conservation and recovery (Senn 2016). However, this coordinated effort is contingent upon the willingness of the partners to participate and move forward.

2.3.2.2 Virgin River Resource Management and Recovery Program

In 2002, the VRP was established to coordinate and implement conservation and recovery actions in the Virgin River Basin within Utah. The VRP is a multi-agency cooperative partnership specifically designed to implement the Recovery Plan and the VSCAS (UDNR 2002).

The main goals of the VRP are as follows:

1. Implement actions to recover, conserve, enhance, and protect native species in the Virgin River Basin, and

2. Enhance the ability to provide adequate water supplies for sustaining human needs.

The VRP seeks to implement these goals in a holistic ecosystem-based manner by coordinating and managing competing land uses and water resources throughout the basin, including efforts to recover, conserve, enhance, and protect native species and their habitat, while balancing and accommodating recreational and consumptive needs required for the growing human population in the basin. In order to implement conservation and recovery efforts in Utah, the VRP focuses on the following actions:

- Coordinate the implementation of the Recovery Plan, VSCAS, and Virgin River Management Plan.

- Promote the recovery of listed species, prevent the need for further listing, and improve habitat conditions for wildlife.

- Take an adaptive management approach by gathering, reviewing, and incorporating biological data and information annually.

- Serve as a basis for determining whether recovery is achieved sufficient to offset project effects.

Through these actions, the VRP has made significant progress over the past decade on woundfin and Virgin River chub recovery and conservation. The achievements of the VRP can be summarized according to the five main goals of the Recovery Plan and are as follows:

1. The VRP has continued and expanded monitoring efforts; coordinated the construction of nonnative fish barriers on the Virgin River, washes, and irrigation returns; worked with UDWR to limit nonnative sport fish introductions into the Virgin River Basin; and conducted chemical treatments to eradicate red shiner and other nonnative species.

2. The VRP has worked to develop instream flow recommendations, improve local floodplain and erosion ordinances, and collaborate on the purchase of areas within the 100-year flood plain to protect against further habitat loss.

3. The VRP established refugia populations of woundfin and Virgin River chub and funded genetic studies to compare wild populations to their respective broodstocks.

4. The VRP constructed a fish screen on the WFD to reduce entrainment of woundfin and other native fish, requested releases of water from Kolob Reservoir during summer months, and coordinated with the WCWCD to implement a pumpback system to increase instream flows between La Verkin Springs and WFD during summer months to reduce stressful conditions.

5. The VRP has assisted UDWR on the implementation of an educational outreach program in the Washington County schools, produced educational materials (e.g., brochures, stickers, magnets, tote bags), and developed an educational website.

2.3.2.3 Other conservation efforts

The Virgin Spinedace Conservation Agreement and Strategy – The Virgin spinedace (*Lepidomeda mollispinis*) is a minnow endemic to the Virgin River Basin. By 1994, threats to the species reduced Virgin spinedace populations to approximately 60 percent of their historic distribution (Valdez et al. 1991; Addley and Hardy 1993). As a result of these threats, the Virgin spinedace was proposed for listing in 1994 as a threatened species under the ESA. The VSCAS was developed in 1995 in accordance with the ESA to improve conditions which had resulted in the decline of Virgin spinedace. The corrective actions to reverse the declines included enhancing habitat, and reestablishing locally extirpated populations throughout the Virgin River Basin (Lentsch et al. 1995). Management actions outlined in the VSCAS alleviate factors which otherwise could contribute to the need for listing under the ESA and also contribute towards recovery of woundfin and Virgin River chub, such as the 3 cfs release at the Quail Creek Diversion. The primary goal of the VSCAS is to increase the range of the species from 60 percent to at least 80 percent of its historically occupied habitat.

The Washington County Habitat Conservation Plan – In 1996, The Red Cliffs Desert Reserve (Reserve) was established as part of the Washington County Habitat Conservation Plan (HCP) to resolve conflicts between development pressures and desert tortoise conservation efforts. This plan was specifically designed to protect the Mojave Desert tortoise (*Gopherus agassizii*). Over 8,000 acres of the Virgin River drainage is protected as part of a 62,000 acre Reserve, which was established through the exchange or purchase of private land within the Reserve boundary. Partners of the HCP include the Bureau of Land Management, USFWS, Utah Department of Natural Resources, State of Utah School and Institutional Trust Lands Administration, and other local entities. This collaborative partnership has the primary goal of recovering the threatened desert tortoise while managing recreational activities, land management, and utility projects within the reserve. The establishment of the HCP has been beneficial for protecting riparian habitat important for woundfin and Virgin River chub populations because grazing and mining are prohibited and off road vehicle use is limited (Red Cliffs Desert Reserve 2015).

The Virgin River Watershed Management Plan – This plan was developed by the WCWCD and a variety of local interests in 1998. Its purpose was to improve communication for watershed issues, develop information opportunities for the public, provide water resources to meet the county's needs, address habitat improvement for endangered species, and improve water quality. The plan provides more direction to land developers in the Virgin River basin and focuses on specific resource issues on a sub-basin level (WCWCD 2006).

The Virgin River Conservation Partnership – This partnership was established in 2002 to develop and implement a comprehensive conservation, restoration, and management strategy for the lower Virgin River and its tributaries in Nevada. The partnership is a collaboration of governmental agencies, nonprofit organizations, and stakeholders. The main goals of the partnership are to: 1) conserve and restore the lower Virgin River ecosystem and its tributaries; 2) balance local, regional, and environmental needs and values; 3) coordinate projects and participate in collaborative partnerships; 4) build public awareness; and 5) establish a sustainable partnership (VRCP 2016). To accomplish these goals, the Virgin River Conservation Partnership has worked with entities to try and protect designated critical habitat and maintain instream flows for woundfin and Virgin River chub in the lower Virgin River.

The Virgin River Master Plan – In January 2005, extreme flooding throughout Washington County and southern Utah highlighted the need for coordinated planning along the major river systems in regards to flood and erosion hazards. This plan was initiated in 2007, and focused on habitat and stream channel improvements including channel and floodplain reconstruction, revegetation, future land use planning, and the appropriation of instream flow rights (Natural Channel Design 2007). Implementation of this plan has reduced floodplain encroachment, increased riparian restoration, and provided additional protection of designated critical habitat for woundfin and Virgin River chub along the Virgin River.

The Muddy River Recovery Implementation Program – Development of this program was initiated in 2006 by the Muddy River Memorandum of Agreement and the Intra-Service Programmatic Biological Opinion regarding groundwater withdrawal from the Regional Carbonate Aquifer and conservation measures for the Moapa dace (*Moapa coriacea*) in Clark County, Nevada. The core members of this program include SNWA, USFWS, The Nature Conservancy, and Nevada Department of Wildlife. The goal of this program is to implement recovery actions that promote conservation within the Muddy River ecosystem and provide for mitigation and minimization of effects associated with water development and use. Current efforts are focused on recovery of Moapa dace within the headwaters of the Muddy River and nonnative fish removal. In 2016, the NDOW completed a rotenone treatment in a ~ 3.5 km (~2.2 mi) reach of the mainstem Muddy River just downstream of the headwaters to eradicate Blue Tilapia (*Oreochromis aureus*) and other nonnative fishes (Senger 2016) which also helps improve conditions for the Virgin River chub.

The Virgin River Habitat Conservation and Recovery Program (VRHCRP) – This program is a coordinated, multi-agency effort to conserve and protect species and habitats while allowing the continuation and development of water resource management projects in the lower Virgin River in Nevada. Program partners include the USFWS, NPS, BLM, NDOW, SNWA, Virgin Valley Water District, Clark County, and City of Mesquite. Partners have been working to create a plan for recovery that will ensure success and sufficient funds to implement necessary actions (Krueger 2015). In 2015, agreements for VRHCRP funding lapsed; therefore, implementation of the VRHCRP is suspended until funding can be secured. An amendment to the Mesquite Lands Act has been introduced to the House of Representatives to allow funds from the Southern Nevada Public Lands Management Act to be used for the implementation of the VRHCRP (Secrist 2016). In the interim, the City of Mesquite and the Virgin Valley Water District will continue to participate with the Virgin River Conservation Partnership and the City of Mesquite will continue with plans to work on habitat and wetland mitigation and restoration projects (Secrist 2016).

2.3.3 Fish population management

2.3.3.1 Environmental stressors, perturbations, and climatic trends

Woundfin and Virgin River chub populations in the Virgin River can be limited by various factors. These factors include nonnative fish, drought, altered streamflow regimes, diversions, elevated water temperature, decreased turbidity, water management events, and a decline of optimum spawning and rearing habitat (Hardy et al. 2003; USFWS 2008a; Huizinga and Fridell 2012). While each of these factors has singularly impacted components of the fish community, the synergistic effect of these factors has severely impaired how the Virgin River Basin ecosystem functions and hence resulted in precipitous declines in native fish populations. In addition, these stressors and perturbations may be further exacerbated by extreme natural events, changing climatic trends, and periods of extended drought.

Annual streamflow in the Virgin River was highly variable during the 105-year period of record at the USGS Virgin gage (#09406000) (Figure 18). At the Virgin gage, the highest water year on record occurred in 2005 with 379,402 (AFY) (annual average volume of 524 cfs), and the second highest was in 1922, with 337,021 AFY (466 cfs) (Figure 18). The lowest water year on record at the Virgin gage occurred in 2002 with 61,227 AFY (85 cfs) and the second lowest in 1990 with 69,276 AFY (96 cfs). The lowest average monthly streamflow recorded at Virgin gage was 30 cfs in July 1928, while the highest average monthly streamflow was 1,729 cfs in May 2005.

The high flows in 2005, which had a beneficial effect on native fish populations in the upper river, were characterized as flood flows in the lower river due to large tributary contributions from the Santa Clara River and Beaver Dam Wash. The January 2005 peak in the lower river, as measured at USGS's Littlefield, Arizona, gage (#09415000) was approximately 35,000 to 40,000 cfs; the highest peak on record since the Quail Lake dike breach in 1989. For comparison, flows above the Quail Creek confluence that same year peaked near 13,500 cfs.

Over the past 15 years, with the exception of a few outlier years, drought conditions have persisted in the Virgin River Basin. Extreme water years, both high and low, can act as environmental stressors on native fish populations, limiting reproduction, recruitment, and survival. In high water years (e.g., 2005 and 2010), increased snowpack and precipitation can result in a protracted runoff, which delays reproduction. In 2005, most of the offspring did not grow large enough to survive winter, and those that did were still too small to reproduce in spring 2006. While these higher water years can limit reproduction and recruitment, low water years are especially limiting to native fish populations, primarily as a result of high instream temperatures during the summer (Huizinga and Fridell 2012). Low flow conditions, in combination with high instream temperature, result in the reduction of optimal spawning and rearing habitats and may be a contributing factor in the decline of successful woundfin and Virgin River chub recruitment (Hardy et al. 2003).

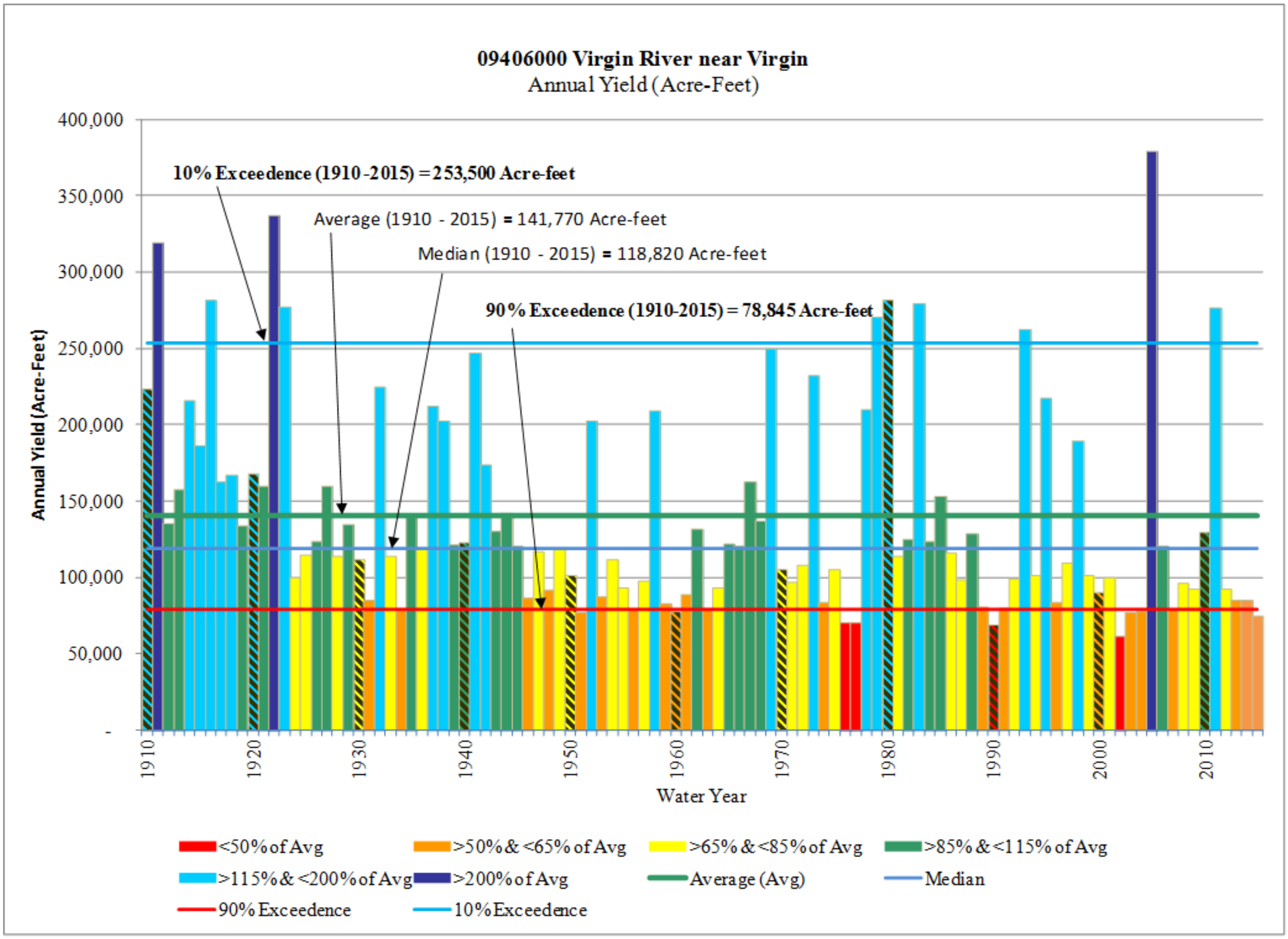

Figure 18. Annual flow (acre-feet per year) in the Virgin River recorded at the United States Geological Survey Virgin gage (#09406000), 1910 to 2015. Note: Figure provided by Utah Division of Water Resources.

Temperature is one of the main environmental stressors limiting woundfin and Virgin River chub populations, with adverse temperatures most likely to occur during summer months. Throughout the Virgin River, daily summer water temperatures can fluctuate by as much as 20°C (36°F) with daily mean temperatures above 29°C (84.2°F) and maximum temperatures reaching 36°C (96.8°F) (Deacon et al. 1987; USFWS 2008a). These summer temperatures exceed the BTM and CTM identified for woundfin and Virgin River chub (Huizinga and Fridell 2012). Instream temperature and instream flow are inversely related. If instream flow is below average, instream temperatures that exceed BTM and CTM occur with greater frequency and duration. For years where stream flow is average or above average, there are less hours where instream temperatures exceed the BTM or CTM. For example, during the past 10 years, instream temperatures during the highest water years (2005 and 2010) in the Virgin River upstream from La Verkin Creek exceeded the BTM < 240 hours and never exceeded the CTM during these years (Figure 19) (Schijf and Fridell 2014). Conversely, during lower flow years (2007, 2013, 2014, and 2015), instream temperatures exceeded the CTM between 463 to 765 hours and the BTM between 14 to 124 hours. While these temperatures limit adult and juvenile fish, it is also likely that extreme temperatures affect the development of native fish eggs and larvae (Hardy et al. 2003).

Water clarity (i.e., low turbidity) is another environmental stressor that can be attributed to declining native fish populations. Woundfin and Virgin River chub are well adapted to living in turbid conditions and use turbidity as cover. Clear conditions make native fish more susceptible to predation due to the increased visibility for predators and congregation of fish into deeper habitats (Hardy et al. 2003; Fridell and Morvilius 2005a). High water clarity may also influence movement of native fish into deeper habitats and areas with cover, rendering preferred habitats unusable and decreasing foraging time and food consumption and ultimately negatively impacting growth, fitness, and survival. For example, when water clarity is high, woundfin congregate in deeper run or pool habitats. The shift in habitat use limits the survival of all age classes by reducing their ability to forage and increases predation potential.

The presence of fish barriers and diversions can also be considered an environmental stressor; however, these structures can have both positive and negative impacts on native fish populations. Diversion structures can be beneficial by impeding or preventing the upstream movement and colonization of nonnative fish into upstream reaches. Conversely, these structures reduce flows and turbidity, change the timing of natural flows, and may limit upstream fish movement. Throughout the southwestern United States, the altering of natural flow regimes due to the construction of dams and diversion structures has been identified as a plausible reason

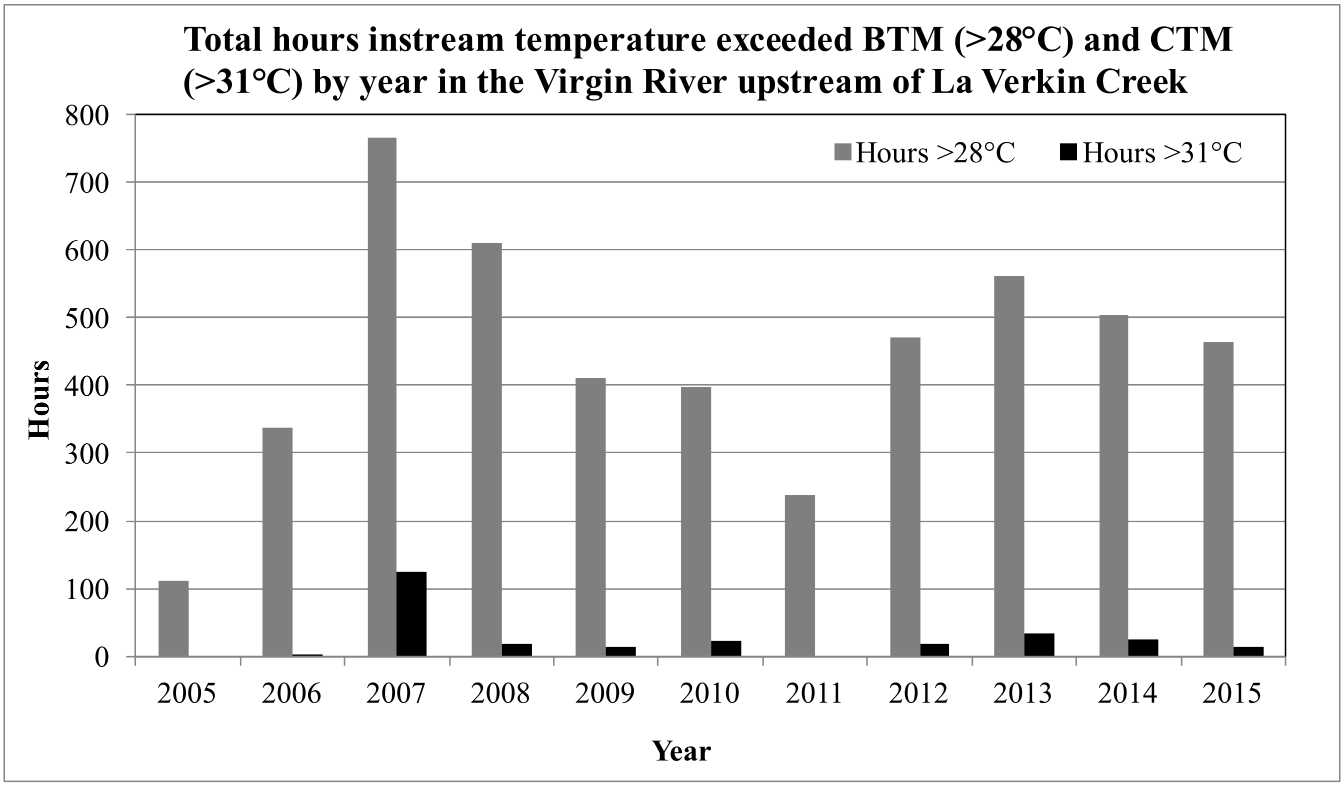

Figure 19. Summary of total hours that instream temperatures exceeded the behavioral thermal maxima (BTM) of >28°C and the critical thermal maxima (CTM) of >31°C, in the Virgin River upstream of La Verkin Creek, 2005 to 2015.

for the decline of native fish species (Deacon 1988; Minckley et al. 2003). When flows are altered, substrate and cover within the stream changes, eventually causing a shift in community composition (Eby et al. 2003). When diversion structures alter the magnitude of storm events or spring runoff, it can affect native fish spawning behavior. The Virgin River does not have dams or diversion structures that remove most of the water during natural high water events. Altered flow patterns may also reduce or eliminate habitat available for spawning (Johnston 1999). In addition, diversions and fish barriers can limit the amount of genetic exchange between reaches by fragmenting native fish populations (Heckman et al. 1986; Deacon 1988; Addley and Hardy 1993; Addley et al. 2005).

Water management activities are another environmental stressor that can have advantages and disadvantages for native fish recovery. Sluicing under controlled conditions has recently been used to reduce limiting factors by increasing turbidity and habitat availability. During a sluicing event, the sluice gate of the diversion is opened to release the water and any sediment impounded behind the structure. The sluicing of anaerobic sediment can result in depressed dissolved oxygen levels in the river and subsequent fish kills (USFWS 2008a). Depending on the accumulation time of sediment, the anaerobic conditions may become more severe.

The Quail Creek Diversion Interim Sediment Management Plan provides minimum discharge, sediment accumulation, and open gate duration recommendations for sediment release events, but does not incorporate suggestions regarding annual timing of sluicing events (Olsen 2004). For example, sluicing during summer high streamflow events coinciding with periods of high temperature, low flow, seasonally lower dissolved oxygen (e.g., 5 to 7 milligrams per liter) or recent fire activity may exacerbate the physiological stress already placed on native fish (Huizinga and Fridell 2012). The District will produce a final sediment management plan incorporating lessons learned in operation of the diversion and monitoring of river conditions.

When the effects of fire are combined with water management activities, the result can be detrimental for native fish. Fire can be a considerable environmental stressor on persistence of native fish populations. Severe fires in riparian areas can cause immediate changes in water chemistry and temperature which can be lethal to fish (Sestrich et al. 2011). After a fire, there can be changes in the timing of runoff, amount of sedimentation, nutrient availability, and water temperature regimes (Dunham et al. 2003). These longer term changes in stream characteristics can also have negative impacts on fish populations (Sestrich et al. 2011).

In a riparian area, post fire impacts can occur as a direct result of the fire or as a combination of interactions between fire and other factors (e.g., climate, topography, land use) (Dunham et al. 2003). Severely burned watersheds are often vulnerable to accelerated rates of soil erosion, which typically lead to large amounts of post fire sediment load and high turbidity (Chen et al. 2013). A limited number of studies have looked at fire disturbance and salmonid fish response, with declines in salmonid populations attributed to post fire debris flows resulting from rainfall on burned slopes (Sestrich et al. 2011; Chen et al. 2013). Unfortunately, for non-salmonid species, the only literature consists of studies on post fire reductions of populations or observations of catastrophic fish kill events (Chen et al. 2013).

As discussed in section 2.3.3.1, a large flash flood carrying ash from an intense fire in July 2007 caused low dissolved oxygen conditions in the river that resulted in a catastrophic fish kill and wild woundfin were essentially extirpated throughout their critical habitat in Utah (Cram 2007; USFWS 2008a; Huizinga and Fridell 2012). Following this event, the VRP funded a study to identify the impacts that runoff or flooding have on water quality following wildfires in the Upper Virgin River Watershed (Chen et al. 2013). This study analyzed historical fire, stream flow, and water quality data and found no correlation between low dissolved oxygen levels and post fire flooding events. Chen et al. (2013) concluded that in addition to fire effects, other mechanisms are involved that led to low water quality issues during these events. In addition, this study could not provide any conclusive evidence that reduced dissolved oxygen levels were associated with sediment loads lethal to fish populations. An unforeseen result of this study was that fire effects in this watershed significantly increase the levels of ammonia already present in the water, and this increase can impact fish since their tolerance level to ammonia decreases as the pH and temperature of water increases. Therefore, post fire runoff occurring during summer may pose severe risks to fish as higher temperatures combined with natural pH levels (usually >7.5) and higher ammonia concentrations, may be contributing to the fish kill events in the Upper Virgin River (Chen et al. 2013).

In addition to the impacts that flow, temperature, water quality, and physical barriers have on native fish, climate change may contribute to these environmental stressors within the Virgin River Basin. Since 1950, the southwestern United States has experienced warmer temperatures than any comparable period in the last 600 years (Garfin et al. 2013). During 2001 to 2010, streamflow within the major drainage basins in the southwest were lower than average flows of the 20th century, with spring runoff arriving earlier (Garfin et al. 2013). While future climate projections are variable in confidence, it is likely that prolonged periods of abnormally hot weather will continue to increase in duration and intensity (Garfin et al. 2013). It is also likely that streamflow will continue to decline in most of the southwest (Garfin et al. 2013). If the effects of climate change continue as projected in the Virgin River Basin, environmental stressors will likely become amplified, as will their effects on the native fish populations.

2.3.3.2 Habitat

Critical habitat for the woundfin and Virgin River chub is the 100-year floodplain of the Virgin River from the confluence of La Verkin Creek to Halfway Wash, Nevada. As a flat area immediately adjacent to streams, floodplains are subject to numerous alterations which affect all native fish species. The sources of these alterations include water diversions, fish barriers, roads, utility corridors, agricultural, residential and commercial development, and invasive species.

In the Virgin River Basin, the use and development of water as a source for irrigated agriculture began with pioneer settlers in the 1850s (Basdekas 2007; see section 2.3.2.1). By 1910, numerous dams and hundreds of miles of canals had been built on the Virgin River and its tributaries (USFWS 1994). As a result of these alterations, the Virgin River has undergone considerable change. Reduction in flows downstream of diversion structures has altered natural flow regimes and resulted in a decrease of available habitat for native fish (Deacon and Hardy 1984; USFWS 1994; Johnston 1999).

Due to the establishment of retirement communities in St. George, Utah and Mesquite, Nevada, growth and development occurred steadily in these cities and surrounding areas since the 1980s. This growth has resulted in infrastructure within, along, and across the floodplain in the Virgin River and its tributaries. Development has encroached upon the river and has necessitated hard armoring (riprap) of erosion barriers or floodplains in many locations for protection of infrastructure.

The final major impact to the 100-year floodplain of the Virgin River is the influx of nonnative invasive fish and plant species. In addition, nonnative fish species and invasive vegetation have displaced native species in many locations throughout the basin. As part of species recovery, three mainstem fish barriers were constructed along with the augmentation of two diversion structures, and three off-channel barriers to prevent the upstream colonization of red shiner.

One of the priorities listed in the Recovery Plan is the protection and restoration of habitat (USFWS 1994). The actions outlined to achieve this goal include: 1) monitoring of habitat conditions for native Virgin River fish, 2) developing and implementing habitat improvements, 3) developing instream flow recommendations, 4) implementing flows and monitoring native fish response, 5) establishing gaging stations and instream flow monitoring sites, 6) identifying water rights for acquisition, 7) acquiring high priority water rights for instream flows, 8) developing legally binding agreements to maintain instream flows, and 9) acquiring land or easements along the Virgin River.

Since 2001, the VRP and UDWR have incorporated the habitat monitoring aspect of these actions into multiple ongoing projects including: PRS monitoring, recovery team monitoring, and Virgin River chub monitoring. The most comprehensive dataset for habitat monitoring is found in the PRS monitoring.

Habitat monitoring is an important component in PRS monitoring (PRS methodology and results are described in section 2.3.1.5). Originally, habitat mapping was designed to ensure PRS monitoring was conducted in proportion to the available habitat at each PRS station. However, PRS habitat mapping has proven valuable as an independent dataset used to evaluate spatial and temporal habitat trends in the upper Virgin River.

PRS locations were established in 2003 and have been continuously monitored since. Three stations are located between La Verkin Springs and the WFD and include above Washington Fields Diversion, Quail Creek (Quail), and above the confluence of Ash and La Verkin creeks (Ash/La Verkin).

During PRS habitat mapping, a map of meso-habitats (distinct units of habitat within the stream) is developed for each PRS station throughout the 2.4 km (1.5 mi) reach. All meso-habitats in each station are recorded and mapped. All available habitat within the wetted channel is classified into the following types: run, riffle, pool, or backwater. Each habitat type is transcribed as an individual polygon onto an aerial photograph and numbered consecutively. The length, average width, average depth, and primary/secondary substrate (silt, sand, gravel, cobble, boulder, and bedrock), are recorded for each polygon.

Habitat mapping was generally conducted at each PRS station biannually in January/February and May/June/July to account for any significant changes in available habitat caused by flow events (e.g. drought, spring runoff, seasonal storms). Exceptions included 2003 (mapping was only conducted in June), 2004 (mapping occurred in May and October) and 2015 (mapping was only conducted in January/February). A complete description of PRS monitoring is included in annual data summary reports (e.g., Bennion and Fridell 2006, and Bennion and Fridell 2015).

To examine habitat trends in this mapping dataset, three of the four original stations were chosen (Ash/La Verkin, Quail, and above WFD). The Quail station is evaluated as two sites: below Quail Creek Reservoir and above Quail Creek Reservoir this station is subdivided into two equal length disconnected reaches in order to detect differences in fish distribution above and below the cold water inflow of Quail Creek

Reservoir and Stratton Pond. These three stations (four sites) were chosen as they are most representative of the hydrology and geomorphology found in the upper Virgin River and can depict overall spatial and temporal habitat trends. Summer mapping was used for all years, except 2015, as it provides the longest most consistent habitat data to summarize this data set below (Appendix H).

Between 2003 and 2015, the proportion of habitat types (run, riffle, or pool) shows a high amount of variation between monitoring stations each year (Figure 20). Generally, the variation in available habitat types decreases at the downstream sites (below QC, above WFD). Since 2003, the overall proportion of run habitat has increased, while pool habitat has decreased. This is especially evident during consecutive low water years (2003 to 2004 and 2013 to 2015). Of the four sites, Ash/ La Verkin and above QC provide the widest distribution of habitat types available per year. During most years, Ash/La Verkin tends to have a higher proportion of riffle habitat and above QC tends to have a higher proportion of pool habitat; however, the proportion of run habitat is very similar between these two stations. At below QC, habitat variability is lower than the upstream sites; however, there is still a higher percent of riffles and pools available than downstream at above WFD, where there is the least amount of variation and runs comprise the majority of habitat available each year (67 to 97 percent); (Figure 20, Appendix H).

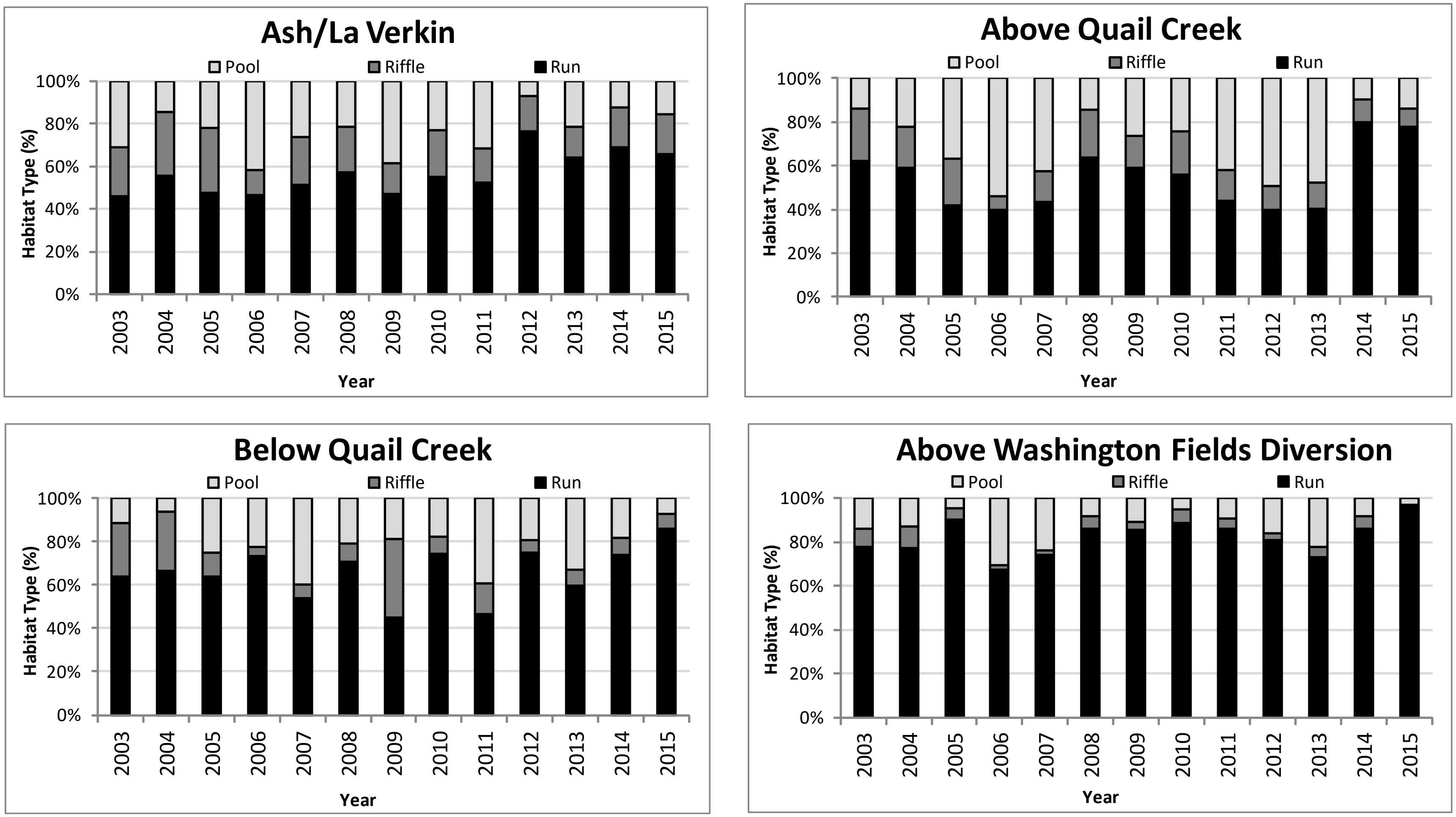

Figure 20. Comparison of percent of the total volume (m3) of habitat by type during population response station mapping for the following stations: Above WFD, Below Quail Creek, Above Quail Creek, and Ash/La Verkin, 2003 to 2015. Note: Backwater habitats are not shown since they comprised <2% of the total habitat by volume.

Typically, streams and reaches with habitat of increased physical complexity are more stable, can support greater species abundance and diversity, and are more resilient to disturbance (Gorman and Karr 1978; Schlosser 1987; Pearsons et al. 1992). Ash/La Verkin and above QC are more physically complex, characterized by having more deep pools, and riffle habitats comprised of large boulders, while the two lower stations, below QC and above WFD, exhibit lower complexity and contain more long sandy runs (Bennion and Fridell 2015). These habitat features also correspond to species habitat preferences. Woundfin generally prefer runs with sand and cobble substrates, while Virgin River chub are found in deeper pools with large boulders (Greger and Deacon 1982; Rinne and Minckley 1991; Hardy et al. 2003; Fridell et al. 2004). Although all native fish species found in the Virgin River can be found at each station, above WFD generally supports more woundfin, speckled dace (*Rhinichthys osculus*), and desert sucker (*Catostomus clarkii*), while Ash/La Verkin supports a more equal distribution in species composition (Huizinga and Fridell 2012). Together, the habitat features, availability, and complexity (Gorman and Karr 1978; Schlosser 1987; Pearsons et al. 1992), as well as the native fish habitat preferences contribute to the higher native fish abundance levels present in the Ash/La Verkin station (Huizinga and Fridell 2012).

Monitoring in Arizona and Nevada consists of biannual Recovery Team Station monitoring and contract work by Bio-West Inc. These projects provide baseline fish population and trend data as well as detecting and monitoring habitat trends (see section 2.3.1.5). In addition to monitoring, the VRP has worked to mitigate habitat degradation by collaborating with various organizations to purchase or secure easements within the 100-year floodplain in Utah (USFWS 2008a). The VRP has also partnered with various city, county, and state and federal agencies to mitigate and restore impacts to riparian areas through restoration activities and implementing stream alteration permit processes to avoid or minimize impacts to native fish and their habitat.

The long-term success of recovery efforts is based upon the ability to protect and enhance habitat. Efforts towards protection and enhancement are ongoing through habitat acquisition by interested parties. By acquiring habitat through interested parties, the habitat generally receives more protection than is available when properties are owned by private individuals. The focus of habitat acquisition and enhancement is to allow the Virgin River to behave in a more natural way, with some restrictions on its ability to meander as a result of the need to protect existing infrastructure. Enhancement efforts also focus on the removal of nonnative and invasive vegetation and reestablishment of native vegetation. Both acquisition and enhancement activities are actively pursued not only by the VRP, but also by local communities.

In 2006, the VRP included the southwestern willow flycatcher (*Empidonax traillii extimus*) as another species of concern. Critical habitat for the flycatcher overlaps with woundfin and Virgin River chub. As a result, the majority of critical habitat enhancement has been directed to areas where efforts are likely to benefit all species through the removal of nonnative vegetation and revegetation with native species.

Floodplain Acquisition

Agricultural use or development has occurred in the 100-year floodplain of the Virgin River through time. Initial uses of the floodplain were for grazing livestock and agricultural uses due to the proximity of water available in the Virgin River; however, the flashiness of the Virgin River has long presented a challenge for agricultural and developmental uses.

Following flooding in the Virgin River Basin in 2005, a Virgin River Master Plan (VRMP) was created by the WCWCD and local communities to prevent and mitigate future damage. The VRMP provides recommendations for use or development in the Virgin River floodplain and encourages development close to the river to be limited to trails, parks, and constructed wetlands.

Flooding in 2005 also necessitated streambank stabilization projects that involved the placement of several miles of rock revetment along the floodplains of the Virgin and Santa Clara Rivers, and Ash and La Verkin Creeks (USFWS 2005b). The effects of these revetments on channel dynamics are unknown; however, they inadvertently created short term refuges for red shiner, which complicated rotenone treatment efforts after construction was completed (USFWS 2008a, Rehm and Fridell 2007).

The protection and rehabilitation of habitat is also facilitated by the establishment of floodplain management ordinances in communities along the Virgin River and its tributaries. These ordinances limit development within established flood and erosion zones in the floodplain by requiring additional inspection and approval from an engineer prior to development (Natural Channel Design 2007; FEMA 2014; and Sterling Codifiers Inc. 2016). All communities adjacent to the Virgin River and its tributaries have adopted floodplain ordinances in the upper Virgin River (Utah) (Sterling Codifiers Incorporated 2016). In 1999, the following entities adopted an Erosion Hazard Zone (EHZ) into their floodplain ordinance: Washington City, City of St. George, Santa Clara City, Washington County, State of Utah, and the Federal Emergency Management Agency (FEMA). The addition of the EHZ expands the area of the floodplain, which serves to limit construction or development activities in these areas (FEMA 2014). The EHZ mapping and study was done by the WCWCD and local cities as part of the Virgin River Master Plan.

Overall, the hazards and regulations associated with building in the floodplain help to protect Virgin River habitat, but do not guarantee its protection. Development of floodplain areas has typically occurred in the upper Virgin River basin near St. George and included filling of the 100-year floodplain for commercial buildings and recreational trails.

The best means to ensure protection of floodplain habitat is through land purchases or conservation agreements. There are over 61,000 acres within the 100-year floodplain between Zion National Park and the Utah State line. Ownership is divided among municipal, state, Federal, and private entities with the majority being privately owned (Layton 2016) (Figure 21). Land ownership within the lower Virgin River floodplain in Arizona and Nevada includes over 51,000 acres divided among private, state, and Federal entities, with the majority being federally owned (Entrix 2008) (Figure 22).

In the upper Virgin River, public and private organizations have acquired land within the floodplain for habitat or municipal protection, including the WCWCD, City of St. George, Washington City, The Nature Conservancy, and Washington County (Meismer 2016a). These areas include land near Rockville (The Nature Conservancy), property in Washington City (WCWCD), land at Confluence Park (location where Ash Creek and La Verkin Creeks meet the Virgin River) in Hurricane/La Verkin with an easement to UDWR (Washington County), and additional property in Confluence Park (WCWCD) (Meismer 2016a). The cities of St. George and Washington have been proactive in acquiring lands in the floodplain to help reduce development pressures. The cities have also been willing to allow and participate in tamarisk (*Tamarix spp.*) removal projects as well as revegetation projects on their respective properties. In the lower Virgin River efforts are also underway to acquire private land in the floodplain within Clark County, Nevada.

In addition to the acquisition of land at Confluence Park (upstream extent of critical habitat), fish passage on La Verkin Creek has been created by trading water rights on La Verkin Creek for irrigation shares. This agreement allowed year round water and included installation of a fish passage structure (Wilson Fish Passage) that provided an additional 4.8 km (3.0 mi) of habitat before the next diversion upstream. Following completion of the passage in 2007, Virgin River chub moved upstream to occupy this new section almost immediately (Meismer 2016b).

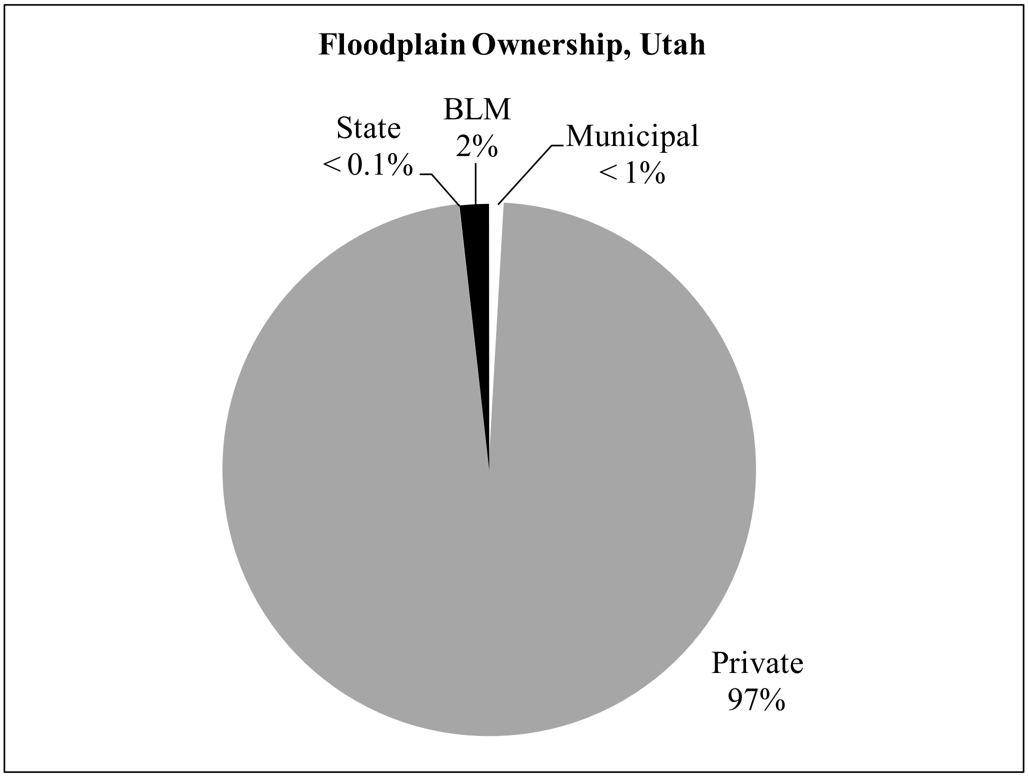

Figure 21. The percentage of land ownership within the Virgin River floodplain in Utah.

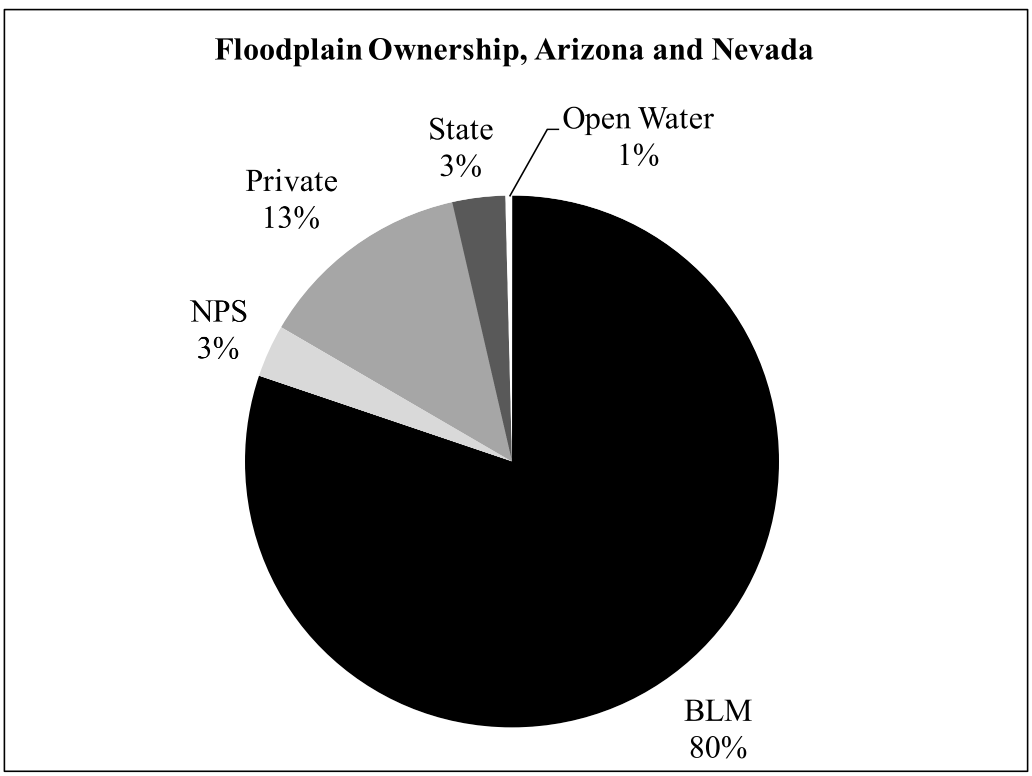

Figure 22. The percentage of land ownership within the Virgin River floodplain in Arizona and Nevada (adapted from Entrix 2008).

Along with the water rights associated with the Wilson Fish Passage, other water rights have been acquired or leased by the WCWCD and the VRP for the benefit of native species. For example, 3.0 cfs of water is required to pass the QCD (UDNR 2002); 0.75 cfs of water was acquired in lower La Verkin Creek for fish benefit in 2000; and the WCWCD often releases flows as necessary to augment or diminish flows to address needs in the summer or during rotenone treatments to manage rotenone detoxification.

While all of these combined efforts benefit woundfin and Virgin River chub, one of the largest and most effective efforts to recover these fish and their habitat has been the development of the pumpback system. Completed in 2012 by the WCWCD, this project pumps water from Sand Hollow Reservoir through the Quail Creek Pipeline to irrigators in the Hurricane Canal Company (see section 2.3.2.1). This pumped water offsets a portion of the amount of water that is needed to be diverted from the Virgin River during summer months. In addition, keeping this additional water volume in the river serves to reduce critical summer temperatures by hundreds of hours.

Innovative ideas such as the pumpback system and water rights leasing or acquisition will likely continue to be necessary in the future to improve habitat for native fish. The continuation of these options and activities are imperative for the persistence and recovery of woundfin and Virgin River chub.

Habitat Restoration

By preventing further development pressures on the Virgin River floodplain, the benefits provided by habitat acquisition are likely to support native fish recovery efforts. However, once a property is acquired, nonnative removal and revegetation is usually necessary. The Virgin River is a flash flood prone system, where flows can go from a few hundred cfs to several thousands in a short period (sometimes in less than a few hours). This propensity to flood, along with the sandy nature of the streambanks, results in a riparian area that can move and change drastically following each storm event. Having the ability and permission to reestablish native vegetation on scoured banks serves the wildlife by outcompeting nonnative plant species as well as helping the local community by planting flexible stemmed vegetation (i.e., willow as opposed to tamarisk). The VRP along with many other community partners are addressing the habitat restoration goals of the Recovery Plan by working to enhance riparian and 100-year floodplain habitat (UDNR 2002).

Nonnative tamarisk is one of the greatest threats to native riparian habitat along the Virgin River. Tamarisk was introduced into the United States for various purposes in the 1830s (e.g., ornamental, windbreak, and river bank stabilizer). Tamarisk can dominate riparian vegetation by creating monotypic stands that alter normal river function and restrict stream channels (USFWS 2008a). The establishment of tamarisk has altered channel morphology and reduced sediment transport within the Virgin River (Hardy et al. 2003). Due to its taproot system, tamarisk is able to establish in upper terraces of the floodplain that cannot be colonized by willows (due to aridity). Other native species have been eliminated by the hypersaline soils attributable to tamarisk presence and high salinity water discharged into the Virgin River (UDEQ 2004). Therefore, it is difficult to establish new vegetation in those areas. Currently, efforts are being made to revegetate these upland areas in the St. George area through surface grading and supplemental water sources to ensure planting success. If initial attempts are successful, expanding this technique could be instrumental in restoring floodplain habitat in the Virgin River.

There are no areas of the floodplain within critical habitat that are immune from tamarisk. Areas that will require significant attention for tamarisk removal include any areas where the floodplain widens out making it easier for tamarisk to outcompete native species. Areas along the Virgin River above WFD and off-channel sites such as Seegmiller Marsh are areas where tamarisk removal will likely be most important for native fish and flycatcher recovery efforts.

Flooding in the Virgin River Basin in 2005 removed large thickets of tamarisk and scoured stream channels. This provided optimal conditions along the Virgin River for numerous native revegetation efforts (USFWS 2008a). Since 2005, local communities have partnered with the VRP on habitat enhancement, tamarisk control, and mitigation projects along the streams of the Virgin River Basin on over 100 acres of floodplain. Between 2012 and 2015, UDWR removed and treated tamarisk on approximately 10 acres and planted almost 3,000 willow stems. In 2015, additional acreage was removed by American Conservation Experience (ACE) at Riverside Marsh, River Road Bridge, Seegmiller Marsh, and above Johnson Diversion with coordination provided by UDWR.

In addition to mechanical removal methods of tamarisk, biological control methods are also being used. In 2006, tamarisk beetles (*Diorhabda elongata*) were released in the Virgin River Basin (Nagler et al. 2017). It took two years to see measurable results; however, since 2008, the beetles have annually defoliated tamarisk plants at least once and occasionally twice a growing season. The beetles have assisted with tamarisk control and removal efforts in two ways: 1) by stressing the plants repeatedly causing death in some cases; and 2) by defoliating the plants prior to flowering, thus reducing the seeding potential (APHIS 2005). One of the mechanisms the VRP uses to reduce that impact is to remove the dead tamarisk, plant native willow and cottonwood species in riparian areas soon after tamarisk defoliation and allow the native vegetation to establish before tamarisk re-establishes at the site. While the beetles will never eradicate tamarisk, they do offer a mechanism for control as communities continue to work at removal and revegetation.

Another introduced plant that can negatively impact riparian areas in the Virgin River floodplain is arundo (*Arundo spp.)*. Following the 2010 flood, arundo colonized several locations along the Virgin River, Santa Clara River, and La Verkin Creek. From 2012 through 2015, the VRP partnered with ACE under a grant from Utah Department of Agriculture and Food to remove arundo from various locations. The UDWR assisted in removal efforts and coordinated with ACE to provide information concerning river access points and property ownership. UDWR also helped to identify locations of large stands of arundo from Confluence Park in Hurricane/La Verkin downstream to the Stateline Barrier. Efforts from 2012 through 2015 resulted in hundreds of hours removing thousands of arundo plants along the Santa Clara River, La Verkin Creek, and in the Virgin River between Confluence Park and the Arizona border. In 2015 alone, 22.4 acres of invasive species were removed including arundo (over 1,600 stands), tamarisk, and Russian olive (NFWF 2015).

Restoring the 100-year floodplain of the Virgin River is important to recovery efforts for woundfin and Virgin River chub because tamarisk and other nonnative species have reduced the ability of the river to function naturally. Reestablishing that natural function will benefit the native species found within the floodplains of the Virgin River with greater success than long term management.

Stream Alteration Process

In addition to the ESA, other Federal and state laws provide protection for woundfin and Virgin River chub populations and their habitat. Section 404 of the Clean Water Act (Public Law 92-500) is a Federal law that regulates dredged and fill material discharge into waters of the United States. Section 404 also requires a stream alteration permit process to make alteration to riverine systems. In addition to Federal law, some State regulations also help to regulate stream alterations. Utah Code (73-3-29) states: "…a state agency, county, city, corporation, or person may not relocate any natural stream channel or alter the beds and banks of any natural stream without first obtaining the written approval of the state engineer." The States of Arizona and Nevada do not have similar regulations for stream alteration permits. In 1985, the U.S. Army Corps of Engineers entered a joint permitting program with the State of Utah, which allowed the state engineer to issue Section 404 certifications. One of the most important conditions is that a proposal will receive additional review if the project will adversely affect a listed species or the critical habitat of these species.

In accordance with these laws, when construction activities are permitted within the Virgin River and its tributaries, fish clearances are required by state permitting agencies in order to avoid direct impacts of stream alteration projects on native fish species. Prior to any instream work (e.g., diversions, crossings, bank reinforcement, etc.), fish clearances are required to salvage and translocate native fish out of the project area. Fish clearances are typically conducted at no charge to the permit applicant by UDWR through funding provided by the VRP.

In order to prevent take of endangered fish species and avoid, minimize, or mitigate any negative impacts that these projects have on native fish, the VRP and UDWR have established the following protocols for all stream alteration projects:

- Construction activities and/or equipment are not permitted to occur within the active flowing channel without a clearance and/or approval from UDWR.
- Construction activities are not allowed during fish spawning season (April 1 – July 31).
- Any rock wall/riprap construction or repair work must include measures to prevent the creation of refuge areas for nonnative fish (e.g., fabric barriers, jetting, grouting, etc.).
- Native woody vegetation (especially willows and cottonwoods) is to be left undisturbed where possible, and any areas where vegetation removal occurred must be revegetated with appropriate native species.

For stream alteration projects, the applicant is required to contact UDWR prior to beginning any construction activities to schedule fish clearances. If the project requires dewatering of the stream or a portion of the stream, the applicant and UDWR meet in advance to develop a strategy to minimize project effect on native fish species. When fish clearances are required, UDWR schedules a day/time to meet with the applicant onsite and perform clearance activities in all areas of impact by depletion monitoring using one or more of the following methods including seining, trapping, and/or electroshocking. Fish captured during clearance efforts are translocated upstream or downstream of the construction area at the discretion of UDWR biologists.

Over the past 10 years, UDWR has conducted an average of 33 fish clearances per year in the upper Virgin River and tributaries, ranging from two clearances in 2007 to 68 clearances in 2014 (Bennion 2016, pers. comm.). In the past five years, over 110,000 native fish were captured and translocated during clearance efforts (Bennion 2016, pers. comm.). While woundfin and Virgin River chub comprise a small percentage of the fish captured, these clearance efforts are successful in reducing take of these endangered fish as well as the listing of other native fish species.

2.3.3.3 Nonnative fish management

The introduction of nonnative species into rivers in the western U.S. has shown to reduce the viability and fitness of native fish through predation and competition for resources (Moyle et al. 1986; Heckman et al. 1986 and 1987; Carlson and Muth 1989; Addley and Hardy 1993; Olden et al. 2006). In the Virgin River Basin, the introduction and establishment of nonnative fish species has impacted the natural reproduction and persistence of native fish, resulting in declining populations (Deacon 1988). The establishment of nonnative fish is considered one of the reasons for the decline of sustainable woundfin and Virgin River chub populations.

While other biological factors, such as invasive plants and increased levels of parasitism, and anthropogenic factors, such as reduced flow, contribute to the decline of woundfin and Virgin River chub, red shiner have largely displaced native fish downstream of the WFD (Deacon 1988; Holden et al. 2001; Fridell et al. 2003; Huizinga and Fridell 2012). Red shiner negatively impact native fish populations through predation of young and direct and indirect competition for habitat and food resources (Addley and Hardy 1993; USFWS 1994; Fridell et al. 2003). The increase in red shiner populations correlates with the decline of woundfin and other native fish species (Cross 1975; Cross 1978). A fairly strong negative relationship occurs when woundfin abundance is regressed against red shiner abundance at the Beaver Dam Wash recovery team station (Holden et al. 2001). However, continuing declines of woundfin and Virgin River chub populations in areas free of red shiner demonstrates that the introduction of red shiner is not the only factor limiting sustainable populations.

Red shiner were likely first introduced as bait fish in the lower Colorado River in the early 1950s, and were abundant in the lower Virgin River (downstream of Mesquite, NV) by the late 1970s (Cross 1975; Miller 1952). Red shiner began to flourish in the lower Virgin River by 1986 and 1987. In 1984, red shiner were detected in the Virgin River near St. George, Utah (Heckman et al. 1987). By 1985, red shiner were abundant in the reach below Johnson Diversion, and by 1986, they dominated the population (Deacon 1988).

The rapid increase of red shiner abundance and distribution throughout the Virgin River Basin demonstrates their ability to tolerate a wide range of conditions and habitats (Marsh-Matthews and Matthews 2000). Red shiner are considered to be highly adaptive generalists and can occupy a wide range of habitat and exploit a variety of food resources, streamflow regimes, and water quality conditions. Red shiner prefer temperatures ranging from 12 to 27°C (53.6 to 80.6°F), with a CTM of 39°C (102.2°F) (Schumann 1978; Deacon et al. 1987). In addition, red shiner have a high fecundity, reproducing throughout the summer, even in low flow conditions, thus allowing populations to rapidly increase in recently colonized reaches.

A variety of management actions have been put in place in response to red shiner colonization including monitoring projects, mechanical and chemical removal, and establishment and maintenance of barriers to prevent the upstream movement of nonnative species.

With the establishment of the VRP, a plan to eradicate red shiner from the Virgin River Basin was developed. The removal of red shiner was identified as critical to achieving the recovery goals outlined by the VRP and the Recovery Plan Team (Comella and Fridell 1998; Fridell et al. 2003). The eradication plan includes the systematic removal of red shiner through the implementation of chemical treatment phases (Fridell et al. 2001). Complete implementation of this plan would eradicate red shiner from the Virgin River system in Utah, and maintain a buffer reach in the Virgin River Gorge below Stateline Barrier, thereby eliminating the threat of red shiner recolonization into Utah. The plan is designed to partition reaches into manageable units (Phases) to ensure that eradication efforts were conducted in an efficient, stepwise, downstream fashion. Phases are implemented in succession between fish barriers. Each phase is repeated until 100 percent red shiner eradication is achieved in each reach.

The treatment plan Phases are as follows: Phase 1 – treatment between WFD and Johnson Diversion; Phase 2 – treatment of the Washington Fields irrigation canals; Phase 3 – treatment of Fort Pearce Wash; Phase 4 – treatment between Johnson Diversion and Webb Hill Barrier; Phase 5 – treatment between the Webb Hill Barrier and Stateline Barrier; and Phase 6 – treatment from the Stateline Barrier to the Virgin River Gorge Barrier.

Phases 1 – 3 were successfully completed through 2004. In 2004, Phases 4 and 5 were simultaneously initiated, and successive rotenone treatments of these phases were implemented annually through 2008 (Rehm and Fridell 2009). The 2008 rotenone treatment was successful at complete red shiner eradication for Phases 4 and 5. In 2009, following the completed construction of the Virgin River Gorge Barrier, extensive planning and procedural preparations were implemented to move forward with the Phase 6 treatment. The majority of Phase 6 is in Arizona. In

2012, state legislation was passed in Arizona (A.R.S. 17-481) requiring environmental review and Arizona Game and Fish Commission approval for the use of rotenone on individual projects. This legislation further delayed treatment implementation.

Although the original Stateline Barrier structure effectively prevents upstream fish movement during low flow conditions, higher stream flow volumes (approximately 700 cfs) may allow red shiner to bypass the Stateline Barrier and colonize upstream reaches. The limitations of the Stateline Barrier were identified in December 2010 when major flooding in the Virgin River allowed red shiner passage above the Stateline Barrier from the Phase 6 reach. Because of red shiner recolonization above the Stateline Barrier, Phases 4 and 5 were again implemented in 2011. Post treatment and full distributional monitoring (2011 to 2013) from Johnson Diversion to Stateline Barrier indicated that the 2011 treatment was successful at removing red shiner in these target reaches (UDWR, unpublished data).

In August 2013, high streamflow again allowed passage of red shiner above the Stateline Barrier. In addition, the Fort Pearce Wash (Phase 3) barrier was destroyed during these high flow events, allowing red shiner to recolonize the Virgin River below Johnson Diversion and Fort Pearce Wash. Intensive mechanical removal efforts were implemented in the Virgin River and Fort Pearce Wash, resulting in the capture and removal of 35 red shiner. Following these efforts, no red shiner were captured during five consecutive full distribution passes of Fort Pearce Wash (October to November 2013) or above the Stateline Barrier during the full pass distribution monitoring (November 2013).

With the success of mechanical removal in Phases 3 to 5, it was a priority to replace the Fort Pearce Wash barrier and improve the Stateline Barrier prior to spring runoff in 2014. In February 2014, improvements to the Stateline Barrier were completed and included the expansion and reinforcement of the splash pad, the addition of wing walls, and an increase in barrier height, with the goal of reducing the likelihood and frequency of upstream red shiner recolonization. These improvements were funded by the VRP and FEMA. In March 2014, the Fort Pearce Barrier was replaced with funding provided by FEMA.

In June 2014, the Phase 6 treatment was conducted by UDWR, AZGFD, NDOW, VRP, and USFWS (Sorensen et al. 2015). Post treatment full pass distribution monitoring indicated that eradication of red shiner from Phase 6 was successful. Unfortunately, following the successful eradication between Stateline Barrier and Virgin River Gorge Barrier, a high streamflow event occurred through the reach in September 2014. During this event peak streamflow at the USGS Above Narrows Near Littlefield gage (#09413700) was recorded at 5,400 cfs on September 8, 2014. Although the Virgin River Gorge Barrier was engineered to be a velocity barrier during high streamflow events and prevent upstream fish passage at any streamflow level, red shiner were captured in-between Stateline Barrier and Virgin River Gorge Barrier during post flood full pass distribution monitoring in November 2014.

Subsequently, modeling conducted by the Utah Water Research Laboratory at Utah State University verified that upstream red shiner passage of the Virgin River Gorge Barrier may be possible at streamflow volumes as low as 1,500 cfs due to design flaws of the barrier (Barfuss et al. 2015). The Utah Water Research Laboratory submitted their recommendations to the VRP including the alteration of the wall on river right to eliminate the low velocity fish passage zone that occurs along the boater portage path and filling the cracks and grouted rip rap with smooth concrete along banks to eliminate low velocity fish refuge areas (Barfuss et al. 2015). The VRP finalized construction plans based on these recommendations and improvements were completed in 2018.

In addition to red shiner, more than 10 other predatory nonnative fish species have been introduced in the Virgin River Basin, including black bullhead (*Ameiurus melas*), black crappie (*Pomoxis nigromaculatus*), brown trout (*Salmo trutta*), fathead minnow (*Pimephales promelas*), goldfish (*Carassius auratus*), green sunfish (*Lepomis cyanellus*), largemouth bass (*Micropterus salmoides*), rainbow trout (*Oncorhynchus mykiss*), smallmouth bass (*Micropterus dolomieu*), and western mosquitofish (*Gambusia affinis*). Although red shiner appear to have the greatest impact, all of these introduced species may contribute to the decline of both larval and adult native fishes (USFWS 1994).

Of these introduced species, the possibility of smallmouth bass becoming established in the Virgin River Basin is of particular concern. Smallmouth bass are a prohibited sport fish in the Virgin River Basin under the VSCAS due to the potential threat they pose to native fish species. In recent years (2005 to 2009), an increase in frequency of angler reports of smallmouth bass captures in Virgin River Basin reservoirs triggered UDWR to conduct surveys within the reservoirs in Washington County from 2009 to 2011. During 2010 monitoring, the presence of smallmouth bass was confirmed in Gunlock and Quail Creek reservoirs by UDWR personnel (Schijf 2016, pers. comm.).

After confirming the presence of smallmouth bass in the Virgin River Basin, a monitoring strategy was developed to determine distribution, relative abundance, and detect expansion of smallmouth bass populations within the basin. Intensive spring and fall monitoring in the Virgin River Basin reservoirs was implemented in 2011 and has been conducted twice annually since. Monitoring results consistently verified self-sustaining populations of smallmouth bass in Gunlock and Quail Creek Reservoirs (Schijf 2016, pers. comm.).

In addition to smallmouth bass captured during reservoir monitoring, two adult smallmouth bass were captured by UDWR personnel during native fish distribution monitoring in 2011. The first was captured in the Santa Clara River approximately 800 meters upstream of Gunlock Reservoir, and the second was in the Virgin River approximately 300 meters downstream of Johnson Diversion. These captures further validated the concern that smallmouth bass, which were illegally introduced into local reservoirs, have the potential for colonizing stream habitat critical for native fish within the Virgin River Basin. The establishment of smallmouth bass in the Virgin River or its tributaries would be highly detrimental to native fish recovery through the loss of habitat, increased predation, and additional chemical treatments to eradicate them (Ottenbacher et al. 2014).

In response to the smallmouth bass colonization of Virgin River Basin reservoirs, a workgroup was created in 2014 to develop an action plan and strategy for the control and eradication of smallmouth bass in the Virgin River Basin. The plan called for immediate implementation of a chemical treatment of Gunlock Reservoir. In October 2015, Gunlock Reservoir was chemically treated to eradicate smallmouth bass from the Santa Clara River drainage. Based on the absence of fish captured during post-treatment monitoring in November of 2015, the treatment was a success. In addition, UDWR personnel annually remove smallmouth bass from Quail Creek Reservoir to control the population in the reservoir.

Annual monitoring continue in Gunlock Reservoir to ensure that smallmouth bass populations do not become reestablished through illegal introductions. In April 2016, Gunlock Reservoir was restocked with largemouth bass, bluegill (*Lepomis macrochirus*), and black crappie (*Pomoxis nigromaculatus*). Although black crappie were not originally an approved sport fish species under the VSCAS, restocking them into Gunlock Reservoir was supported by the Virgin Spinedace Conservation Team as a public outreach action.

In addition, the introduction of blue tilapia (*Oreochromis aureus*), is of particular concern in the lower Virgin River because they pose a threat to native fish recovery in the Virgin and Muddy Rivers. Blue tilapia was first detected in the Muddy River in 1991 (Scoppettone et al. 2005). Blue tilapia quickly expanded downstream and were captured in Lake Mead in 1994. In 2001, they were found in the Virgin River downstream of the Bunkerville Diversion (Golden and Holden 2004).

The arrival of blue tilapia in the Muddy River was followed by a decline in populations of native fishes (Scoppettone et al. 2005). Blue tilapia are considered filter feeders in their native habitat. However, in the Muddy River, blue tilapia switched to fish consumption once they deplete aquatic vegetation (Scoppetone et al. 2005). Therefore, it is likely blue tilapia contributed to the decline of Moapa dace (*Moapa coriacea*), Moapa White River springfish (*Crenichthys baileyi*), and Virgin River chub (Scoppetone et al. 1998).

The Moapa dace and Moapa White River springfish are thermophilic (survive at high temperatures) fish endemic to the Muddy River, and are restricted to temperatures between 26.0 to 32.0°C (78.8 to 89.6°F) (Scoppettone 1993). Temperature tolerances for blue tilapia (20 to 35°C; 68 to 95°F) are similar to those of Moapa dace and Virgin River chub (Scoppettone 1993; Oliveira 2005). In other U.S. streams, the distribution of tilapia is restricted by their low tolerance to cooler water temperatures (Oliveira 2005). The lowest temperatures blue tilapia can survive for an extended period is approximately 12°C (53.6°F) (Golden and Holden 2004). The temperature tolerance for this species helps to explain why they are only captured during summer and fall in the lower Virgin River. The absence of blue tilapia during winter months may indicate mortality or seasonal migration from the Virgin River to Lake Mead (Golden and Holden 2004).

Efforts to monitor and eradicate blue tilapia in the Muddy and Virgin Rivers is ongoing. In fall of 2002, a pilot rotenone treatment was conducted on the Virgin River below the Bunkerville Diversion (Golden and Holden 2004). Since 2002, additional eradication efforts have proven successful, with no blue tilapia captured during monitoring in August 2015 on the lower Virgin River (Biowest 2015, unpublished data). In the upstream reaches of the Muddy River, a combination of chemical and mechanical eradication efforts, ongoing since 1998, have also proven successful (Guadalupe 2016; Rehm 2016). As of August 2015, no tilapia have been captured in any of the reaches upstream of Warm Springs Road (Rehm 2016).

2.3.3.4 Limiting factors

Within the last 40 years the Virgin River has experienced declines in total native fish abundance, including populations of woundfin and Virgin River chub. These declines are primarily due to the loss of range and displacement by red shiner and low instream flows and high water temperatures brought on by water diversion and drought conditions over the past 30 years. Consistently reproducing populations of woundfin and Virgin River chub only occur in the reach between Ash Springs and WFD, where several factors continue to limit their survival, distribution, and abundance.

Two of the most important factors thought to be limiting the survival and persistence of native fish in the reach between Ash Springs and WFD are low summer stream flow and high instream temperatures (Deacon and Hardy 1982; Deacon 1988; Hardy et al. 2003). The importance of temperature and flow regimes to native Virgin River fish is not a new concept. Numerous authors have emphasized how discharge as well as high instream temperatures can impact the Virgin River native fish community (Deacon and Hardy 1982; Deacon 1988; Holden et al. 2001; Hardy et al. 2003; Golden and Holden 2004; Rehm et al. 2006).

In this report, a limiting factor is defined as some aspect of the environment that limits the distribution or abundance of woundfin or Virgin River chub. Over the years, the VRP, Utah State University, and UDWR have evaluated multiple biotic and abiotic factors limiting native Virgin River fish (e.g., temperature, flow, turbidity, sluicing, winter mortality, nonnative fish). It was determined that the two primary factors negatively affecting fish were red shiner in the reaches below WFD and high temperatures associated with low summer flows in the reaches below QCD (biological limiting factors are discussed in section 2.3.3.3 above).

Instream water temperatures can impact numerous physiological processes of all aquatic organisms, including: growth, metabolism, development, consumption and evacuation rates, reproductive success, and disease susceptibility (Feder and Hofmann 1999; Poole et al. 2001; Selong et al. 2001; Addley et al. 2005; Bestgen 2008). Therefore, summer water temperatures directly impact woundfin and Virgin River chub, as temperature affects the productivity of the aquatic food base, growth and survival of larval fish, and behavior and physiological condition of adult fish.

Although summer water temperatures are largely a function of specific weather conditions during a given summer (e.g., ambient air temperature and summer storm events), they are also strongly influenced by the volume of water in the Virgin River. The annual low flow period in the Virgin River typically occurs in the summer (June to September). Summer temperatures and flow often exhibit an inverse relationship; as flows decrease, instream water temperatures increase (Huizinga and Fridell 2012). Extremely low flow can also alter water chemistry, temperature, and dissolved oxygen availability, thereby causing fish considerable stress and even mortality (Huizinga and Fridell 2012). When low flows are combined with high temperatures, these water conditions can lead to severe physiological stress, altered behavioral patterns, increased metabolism, and restricted growth and development. Fish mortality can occur if exposed to these conditions for prolonged periods.

Water temperatures can be influenced by changes in the flow regime, including water depletions. Several studies have demonstrated that a range of flow conditions can also improve aquatic ecosystem function and alleviate stressful thermal conditions on aquatic organisms by incorporating variation in the magnitude, duration, timing, and frequency of flows (Richter et al. 1997; Olden and Poff 2003; Olden and Naiman 2010).

In the Virgin River, conditions limiting native fish begin in June and often persist through July, August, and September. This time period is marked by increased instream temperatures, decreased flows, and decreased turbidity. In addition, these changes also alter the proportion and availability of habitat types. Extremely low flows reduce habitat availability (i.e., low volume and high clarity) and connectivity. As a result of these conditions, fish are often confined to inflows, seeps, springs, pools or other thermal refuge areas. Therefore, these conditions indirectly alter foraging efficiency and increase predation rates of both adult and young native fish (Huizinga and Fridell 2012). Furthermore, water depletion and low flow regimes during summer months exacerbate habitat constraints and temperature extremes already placed on the river system.

While summer temperature and flow regimes are considered one of the factors limiting native fish, the effect these factors have on the native fish community are not homogeneous throughout the upper Virgin River (Utah portion). The hydrology within different reaches of the river can improve or exacerbate summer conditions. Native fish populations may be resilient to a single limiting factor, but the simultaneous or cumulative effects of multiple limiting factors may severely impede recovery actions for woundfin and Virgin River chub.

In the remainder of this section, a brief summary of hydrology and temperature conditions in the upper Virgin River is discussed by reach. Temperature and flow parameters most limiting to native fishes are also highlighted by reach. Corresponding minimum daily discharge for each reach was calculated using incremental data from the following USGS gage stations on the mainstem Virgin River: Virgin (#09406000), Above La Verkin Creek (#09406100), and Hurricane (#09408150). Water temperature data for each reach was collected from corresponding UDWR temperature loggers. Three temperature loggers were used including upstream of QCD (Sheep Bridge), downstream of La Verkin Springs (Above La Verkin Creek), and above WFD (Hurricane Bridge). A complete description of water quality monitoring methods, temperature logger locations, and data is summarized in UDWR reports (Schijf et al. 2012 and 2013; Schijf and Fridell 2011, 2014, and 2015). A more detailed history of water management and use in the upper Virgin River is included in section 2.3.2.1.

Above Quail Creek Diversion

The temperature, flow, and turbidity in this section largely represent natural water quality conditions upstream of QCD and La Verkin Springs (Figure 23). There are a number of diversions which withdraw water in this reach, but the effect on natural riverine conditions is limited. Even under these natural conditions, however, periods of low flow and high instream temperatures can occur periodically, depending on the year. From 2011 to 2015 during summer months (June to August), the lowest recorded discharge by year (minimum summer flow by year) ranged from 36 cfs in 2012 to 81 cfs in 2011 (Figure 24). During this same period, instream temperature exceeded the CTM by zero to five hours, while BTM was exceeded by less than an hour to 141 hours (Figure 25). These numbers are relatively low when compared to the reaches downstream of QCD.

Based on lower summer instream temperatures and generally higher flows above QCD, native fish located in this reach experience less severe conditions and are not subject to the same set of factors limiting native fish in downstream reaches. Unfortunately, woundfin and Virgin River chub populations do not occur in this reach as it is upstream of their historical range, and the QCD prohibits upstream migration.

Quail Creek Diversion to WFD

This reach of the upper Virgin River includes the two principal mainstem diversions, QCD and the WFD (Figure 23). The QCD has the ability to divert a maximum of 250 cfs from the Virgin River. Regardless of base flow conditions, a minimum bypass flow of 3 cfs is released at the QCD in accordance to the VSCAS (USFWS 2008a). The QCD provides water for irrigators, hydropower, and Quail Creek and Sand Hollow reservoirs (the primary sources of culinary water for Washington County).

Approximately 4.7 km (2.9 mi) downstream of the QCD is La Verkin Springs, which is a series of more than 100 hot water vents, adding approximately 11 cfs into the Virgin River (Cross 1985; Gerner and Thiros 2014). La Verkin Springs water temperatures range from 40.0 to 43.0°C (104.0 to 109.4°F); the water is also highly mineralized and is devoid of oxygen (Cross 1985; Gerner and Thiros 2014). The hot water inputs from La Verkin Springs combined with low streamflow and high temperatures result in the springs discharge point being the upstream extent of woundfin and Virgin River chub populations in this reach of the Virgin River. Approximately 2.0 km (1.2 mi) downstream from the first vent of La Verkin Springs, the inflow from the Hurricane Hydropower Plant releases 25 to 30 cfs of cooler water which helps to dilute and cool the stream at the upstream terminus of critical habitat for woundfin and

Virgin River chub. To further alleviate high instream temperature and low flow conditions, a pumpback system was initiated in 2012, and is used during summer months to offset irrigator demand. This additional water is released at the Hurricane Hydropower Plant and is used to increase median discharge and provide pulse events during summer months (for additional information on the pumpback system see section 2.3.2.1).

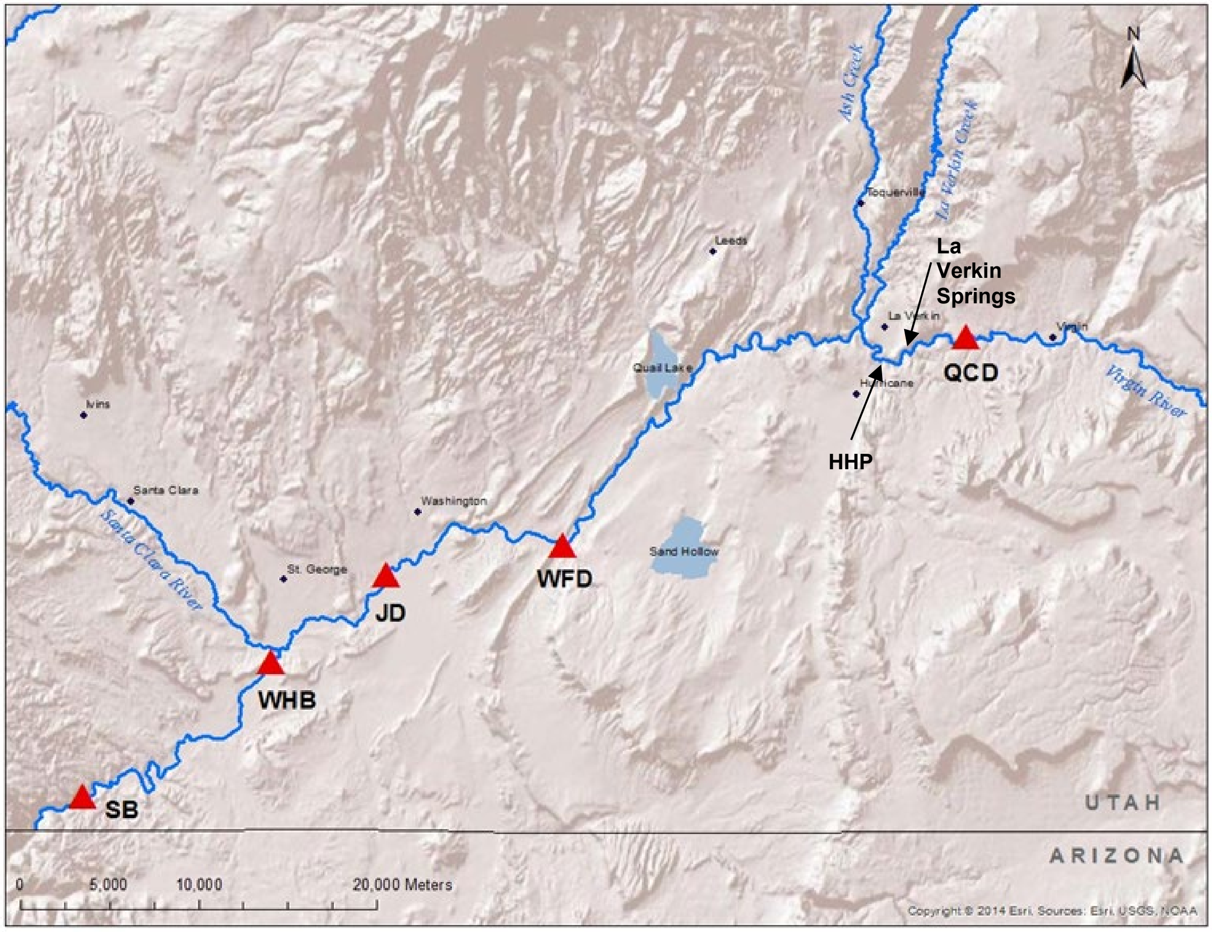

Figure 23. Location of diversion structures on the upper Virgin River in Utah including: Quail Creek Diversion (QCD), WFD, Johnson Diversion (JD), and Stateline Barrier (SB). Note: La Verkin Springs and the Hurricane Hydropower Plant (HHP) are shown for reference. Webb Hill Barrier (WHB) is also included for reference; however, it no longer exists (i.e., sedimentation following high flows in December 2010).

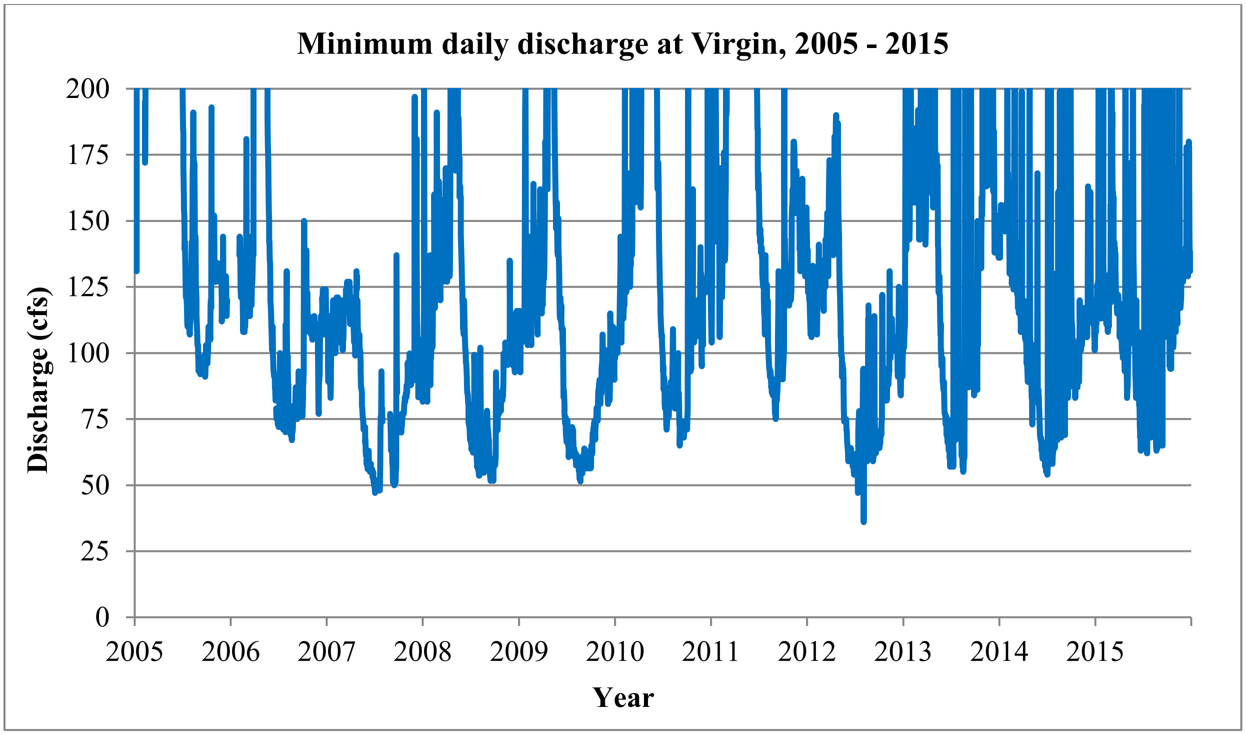

Figure 24. Minimum daily discharge (cfs) recorded on the Virgin River mainstem at the USGS Virgin gage (#09406000), Utah, 2011 – 2015. Note: the y-axis was truncated to best fit the data.

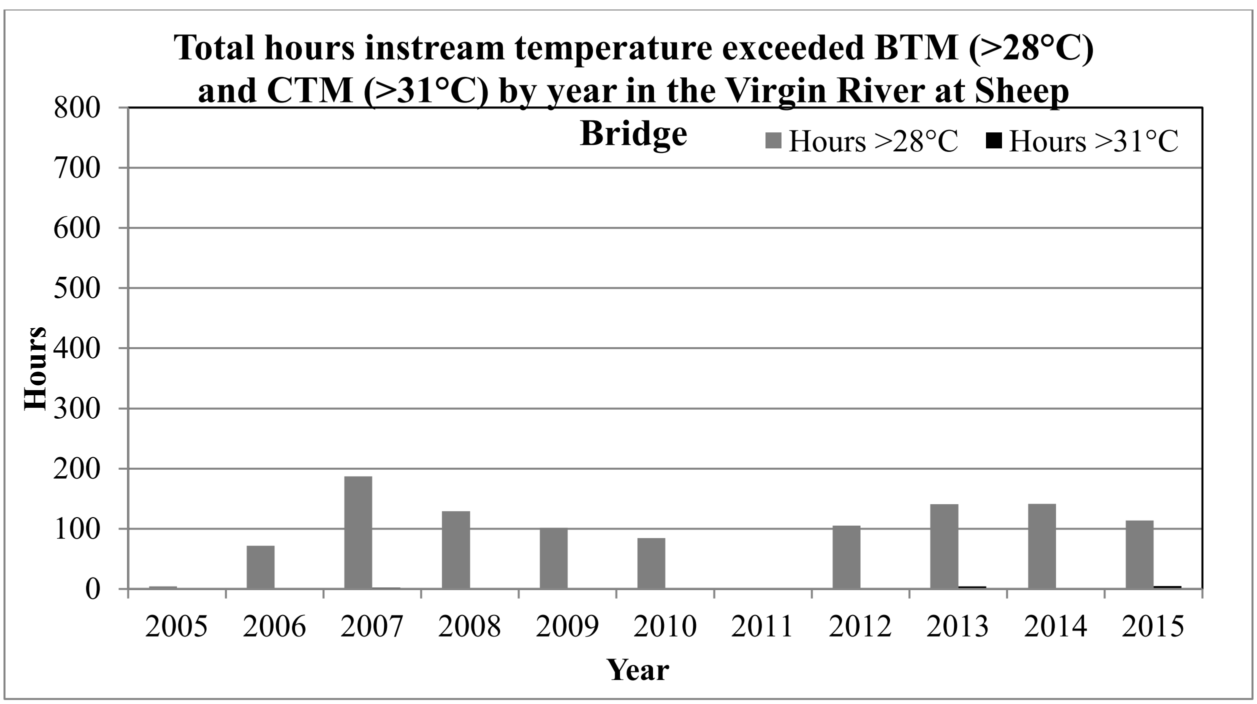

Figure 25. Summary of total hours that instream temperatures exceeded the behavioral thermal maxima (BTM) of >28°C and the critical thermal maxima (CTM) of >31°C, in the Virgin River at Sheep Bridge in Virgin, Utah, 2005 – 2015.

All of the tributary inflows in this reach are downstream of La Verkin Springs and most of these (La Verkin Creek, Ash Creek, Gould's Wash) add minimal flow during summer. Therefore, La Verkin Springs and the Hurricane Hydropower Plant/pumpback water constitute the majority of the streamflow in the upstream reach of critical habitat for woundfin and Virgin River chub. Approximately 14.5 km (9.0 mi) downstream from the Hurricane Hydropower Plant inflow, cool water is released from Quail Creek Reservoir to meet irrigator demands at the WFD (Figure 23).

Temperature and flow in the 26.2 km (16.3 mi) section of river between La Verkin Springs and WFD are the most concerning for native fish, as it is the upstream geographic limit of woundfin and Virgin River chub distribution. In addition, this reach has maintained the largest native fishery over the past 30 years and has never had an established population of red shiner. Therefore, alleviating limiting factors in this reach is necessary for the persistence and survival of woundfin and Virgin River chub.

From 2011 to 2015, in the reach downstream of La Verkin Springs, minimum summer flow by year at the Above La Verkin Creek gage ranged from 19 cfs in 2012 to 32 cfs in 2015 (Figure 26). During this same period, the number of hours instream temperature exceeded the CTM and BTM were much higher than in the reach above QCD; the CTM was exceeded by 0 to 33 hours and BTM was exceeded by 238 to 562 hours (Figure 27). In comparison, further downstream at the Hurricane gage, minimum summer flow by year ranged from 36 cfs in 2012 to 78 cfs in 2011 (Figure 28). Instream temperatures at this site exceeded the CTM and BTM by a wider range; the CTM was exceeded by zero to 144 hours and BTM was exceeded by 79 to 566 hours (Figure 29).

A large scale analysis of fish, temperature, flow, and limiting factors data from 2002 to 2010 found the La Verkin Springs to WFD reach has substantially higher instream temperatures, reduced daily temperature fluctuations, and considerably more hours of exposure above the CTM and BTM than the reach above QCD (Huizinga and Fridell 2012). The maximum and minimum flows were also much different in this reach than above QCD, with less days of maximum flow, corresponding to spring runoff, and more days of minimum flow (Huizinga and Fridell 2012).

WFD to Stateline Barrier

This section includes two reaches; the 10.3 km (6.4 mi) reach from WFD to Johnson Diversion and the 24.5 km (15.2 mi) reach from Johnson Diversion to Stateline Barrier (Figure 23). To date, temperature and flow issues have not been studied below WFD because of the focus on red shiner eradication in those areas.

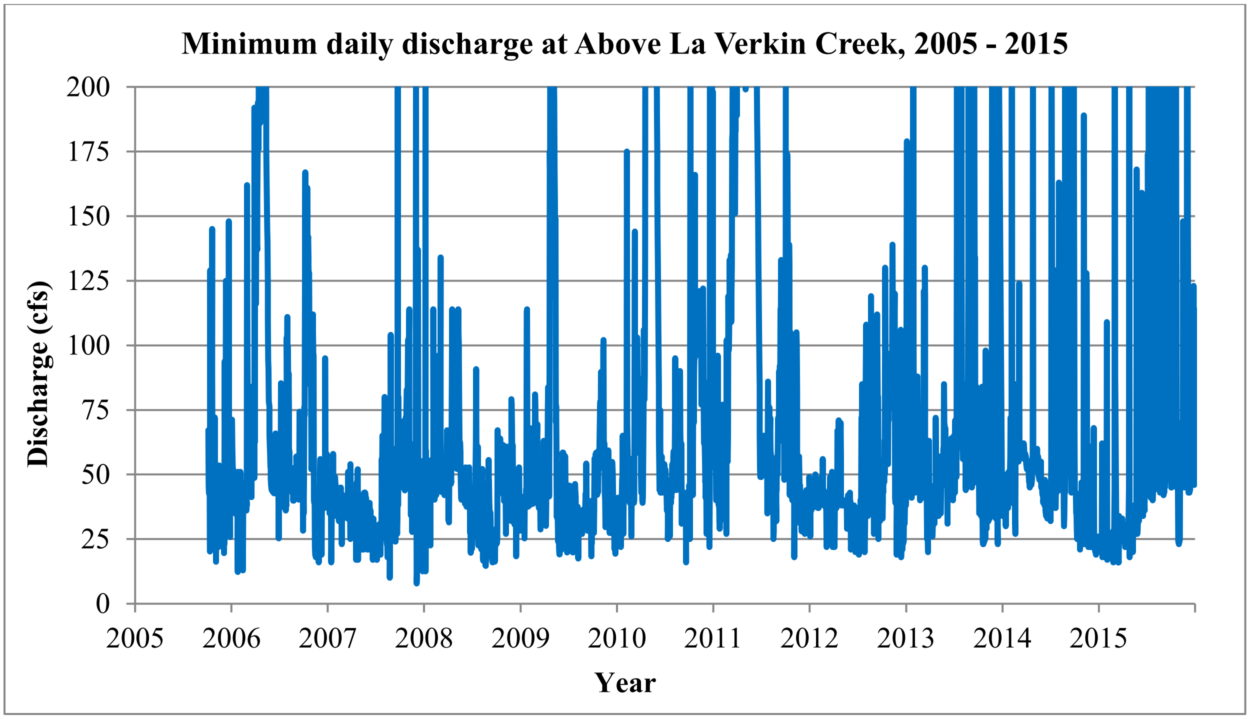

Figure 26. Minimum daily discharge (cfs) recorded on the Virgin River mainstem at the USGS Above La Verkin Creek gage (#09406100), Utah, 2011 to 2015. Note: the y-axis was truncated to best fit the data.

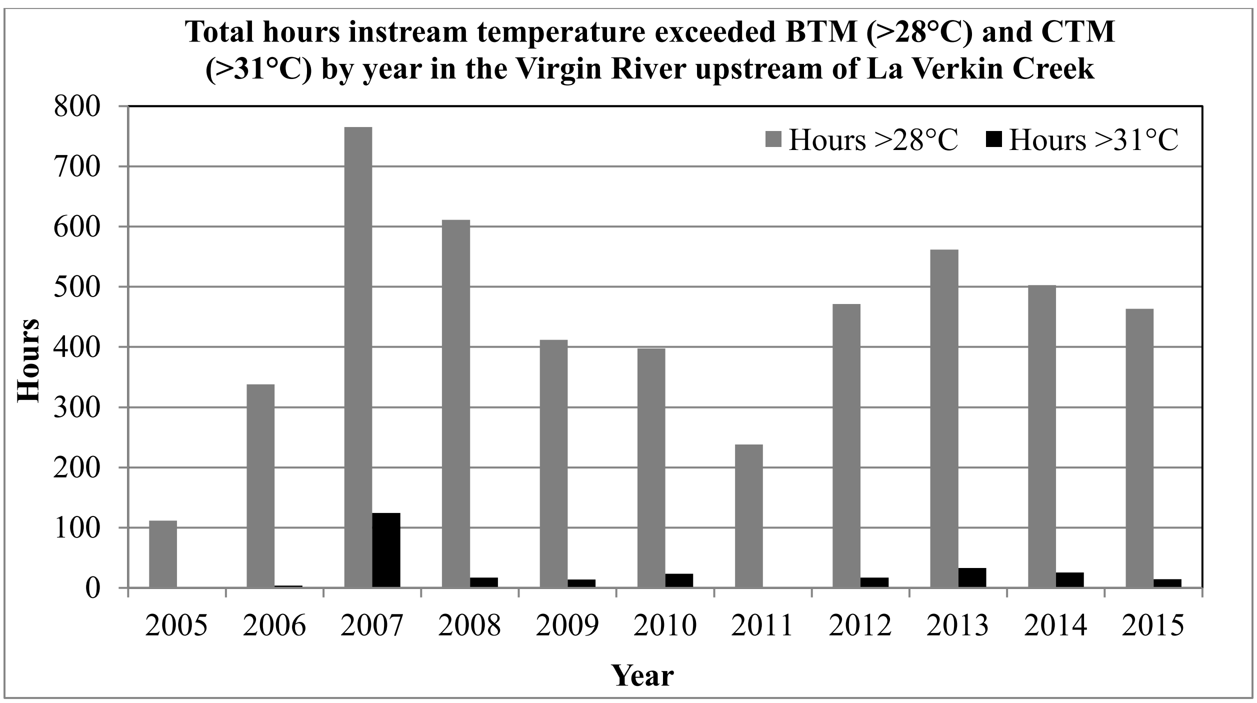

Figure 27. Summary of total hours that instream temperatures exceeded the behavioral thermal maxima (BTM) of >28°C and the critical thermal maxima (CTM) of >31°C, in the Virgin River upstream of La Verkin Creek confluence, Utah, 2005 – 2015.

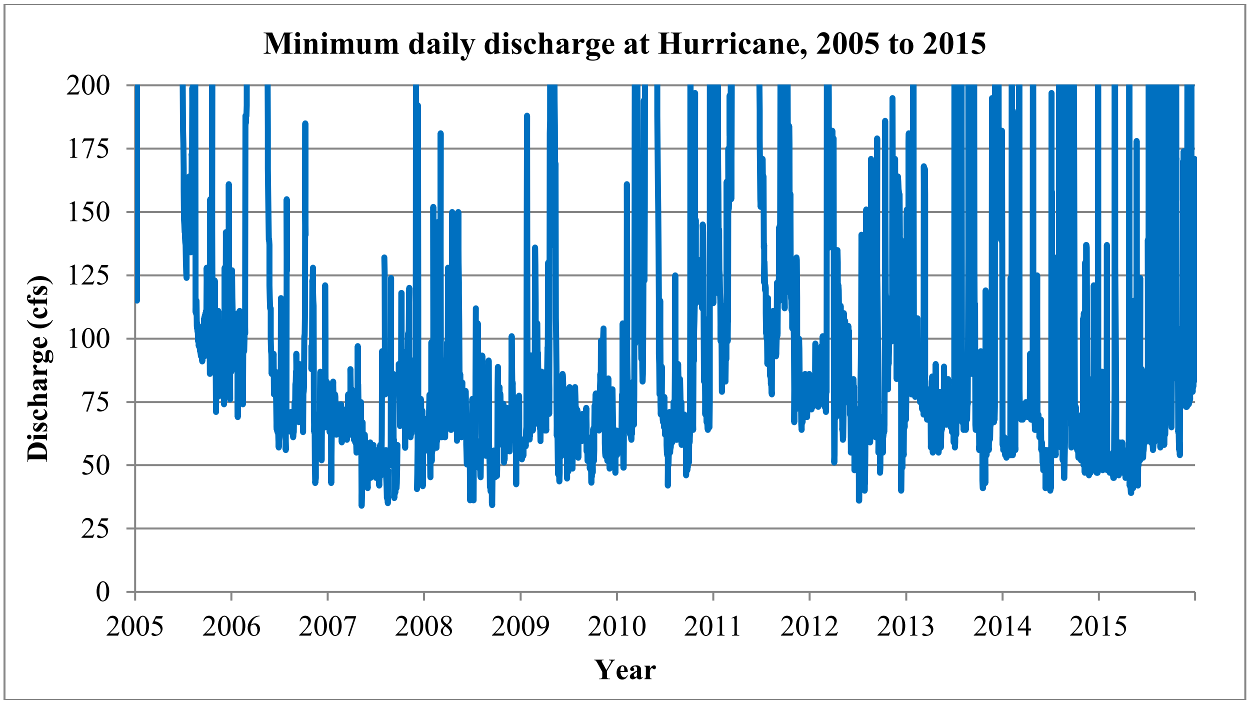

Figure 28. Minimum daily discharge (cfs) recorded on the Virgin River mainstem at the USGS Hurricane gage (#09408150), Utah, 2011 to 2015. Note: the y-axis was truncated to best fit the data.

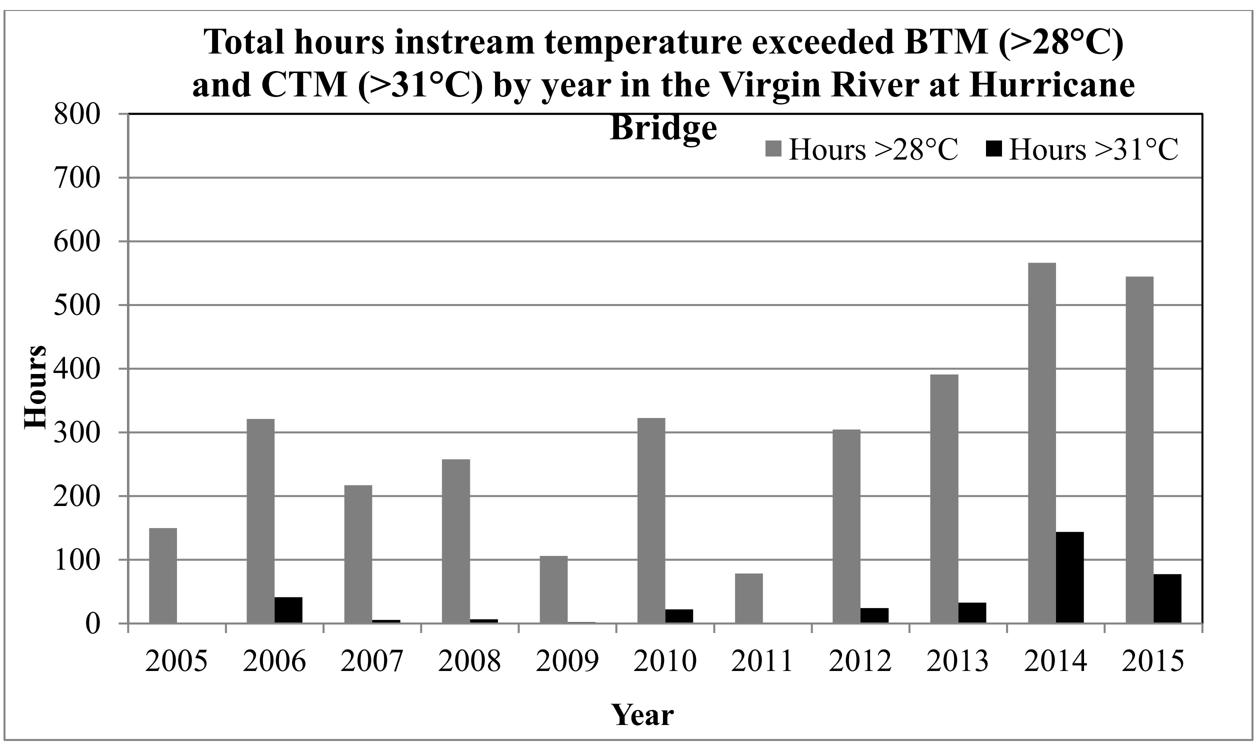

Figure 29. Summary of total hours that instream temperatures exceeded the behavioral thermal maxima (BTM) of >28°C and the critical thermal maxima (CTM) of >31°C, in the Virgin River at Hurricane Bridge, Utah, 2005 to 2015.

Currently, in the reach between WFD and Johnson Diversion, the WCWCD and VRP provide population maintenance flows below the WFD during summer months through the WFD fish screen bypass. The bypass flows in this reach offer the first opportunity to prevent the loss of native fish populations by providing a mechanism to provide instream flows, and thus enhance native fish recovery efforts by maintaining downstream connectivity for native fish populations. Although these bypass flows (approximately 1 to 3 cfs) provided during summer months may help prevent native fish loss and provide connectivity downstream to Johnson Diversion, the exceedance of the thermal maxima will likely prevent this reach from sustaining a viable population of native fish. Due to the lack of water available to provide flows to alleviate summer temperatures, intensive long term management of this section will be necessary to prevent this reach from being a population sink. Water diverted at the WFD returns at several locations between Johnson Diversion and the confluence of Ft. Pearce Wash. These flows provide the majority of baseflow in the Virgin River downstream to the Stateline Barrier.

Stateline Barrier to Lake Mead

From the Stateline Barrier downstream, red shiner and reduced flows have long been identified the most likely limiting factors for the native fish community of the lower Virgin River (Holden et al. 2001; Golden and Holden 2002; Golden and Holden 2004; Albrecht et al. 2007; see section 2.3.1.5).

Downstream of the Beaver Dam Wash station, woundfin persisted (likely supported by periodic releases of hatchery fish) at two locations: at the Mesquite Reach (below the Bunkerville Diversion) and at the Riverside Reach (very near the lower terminus of critical habitat). Monitoring in these areas from 1996 to 2002 showed reported dramatic declines of woundfin and other native species during the drought years of 1999 through 2002 (Golden and Holden 2004). No woundfin were collected by the fall of 2001 and none were collected in 2002, the lowest flow year on record. Since then, woundfin have remained absent in this lowest portion of the Virgin River (Albrecht et al. 2007).

2.3.3.5 Stocking

Background

The stocking of woundfin and Virgin River chub was identified in the Recovery Plan as one of the main actions to maintain and enhance woundfin and Virgin River chub populations. Objectives under this action included perfection of propagation techniques, development of protocols and production goals, and implementation of propagation and reintroduction programs (USFWS 1994).

In order to implement and establish a hatchery program and utilize cultured fish in management efforts as defined by the Recovery Plan, salvage, broodstock, and culture plans for woundfin (Hepworth et al. 2000) and Virgin River chub (Morvilius and Fridell 2006) were developed. Refuge populations for woundfin and Virgin River chub were established and the natural genetic diversity of each species is being maintained to offset potential catastrophic losses in the river and to augment wild stocks (USFWS 1994). Ultimately, the product of these efforts is to establish and maintain viable populations of woundfin and Virgin River chub in the wild.

Broodstock/Refuge Populations

In 1979, woundfin were collected in the Virgin River to establish a captive broodstock and refuge population at SNARRC located in Dexter, New Mexico (USFWS 2008a). Unfortunately, none of the woundfin collected before 1987 survived in captivity, therefore, the present stock is descended from woundfin (n=3,338) brought to SNARRC from 1987 to 1989 (Chen et al. 2009). From 2002 to 2004, additional wild woundfin (n=174) were collected to supplement the captive population (Chen et al. 2009).

In 1989, a refuge population of Virgin River chub was established at SNARRC. A majority of these fish were collected from the upper Virgin River near St. George, Utah (n=162) with subsequent collections from Utah in 2002 (n=455) and 2005 (n=93). In addition, a small number of Virgin River chub (n=28) were also collected in 2002 from the lower Virgin River in Arizona and Nevada (USFWS 2008b).

After the successful establishment and propagation of woundfin and Virgin River chub at SNARRC, the Virgin River Fishes Recovery Team requested a second offsite refuge. Due to the restricted range of woundfin and Virgin River chub, actions outlined in the Recovery Plan justified maintaining broodstock and refuge populations at a minimum of two facilities for the protection of these species. The second offsite refuge for woundfin and Virgin River chub was established at Wahweap State Fish Hatchery (Wahweap), located in Big Water, Utah. In 2001, approximately

1,400 woundfin were salvaged from the Virgin River (prior to a rotenone treatment) and brought to Wahweap to establish the refuge. Unfortunately, most of these fish (98.5 percent; n=1,379) died from a parasitic outbreak of ich (*Ichthyophthirius multifilis*). In 2002, approximately 200 woundfin were transferred from SNARRC to supplement the woundfin population at Wahweap. In January 2007, the Virgin River chub refuge and broodstock population was established at Wahweap. A total of 1,000 Virgin River chub were transferred from SNARRC to Wahweap.

The broodstock and refuge populations are supplemented periodically with wild woundfin and Virgin River chub. Woundfin are managed annually to produce offspring for stocking and Virgin River chub are managed only as a refuge population. Virgin River chub are occasionally produced in excess of hatchery goals and available space. When this occurs, they are stocked in the Virgin River or other refuge sites according to VRP priorities (Morvilius and Fridell 2006).

Until recently, SNARRC and Wahweap maintained refuge and broodstock populations of woundfin and Virgin River chub. In fall 2015, the VRP and Virgin River Fishes Recovery Team restructured the refuge and broodstock populations at each hatchery, based on propagation success rates and facility constraints. Woundfin and Virgin River chub refuge and broodstock populations are now maintained at separate hatcheries. SNARRC is responsible for maintaining the woundfin broodstock and refuge population and producing woundfin to meet stocking goals. Under this new structure, SNARRC holds the majority of the young produced each year in order to obtain the maximum size for stocking and the remaining young are transferred to Wahweap each fall. Wahweap is responsible for the over winter growth (grow-out) of these young woundfin prior to stocking in the upper Virgin River in spring. Wahweap also maintains the Virgin River chub refuge and broodstock population. In fall 2015, all of the Virgin River chub remaining at SNARRC were transferred to Wahweap to allow SNARRC to concentrate on woundfin propagation. In the future, a refuge population of Virgin River chub will be reestablished at SNARRC once woundfin are recovered throughout the Virgin River.

Stocking Accomplishments – Upper Virgin River

Prior to the 2000s, the only record of stocking in the upper Virgin River (Utah) was for Virgin River chub (n=1,290) in 1994, following natural pond recruitment at SNARRC (USFWS 2008b). Starting in 2002, efforts were made to establish off-channel refuge populations for Virgin River chub at locations in the upper Virgin River Basin including Purgatory Pond, Toquerville Pond, and Zitting Pond. Virgin River chub were also stocked periodically in the mainstem upper Virgin River and other off channel areas (Table 2). To date, 24,242 Virgin River chub were stocked in the mainstem Virgin River and 5,864 were stocked in off channel refuge locations (Table 2).

In 2003, in response to extremely low numbers of wild woundfin in the upper Virgin River, the VRP and UDWR began to supplement wild populations with woundfin from SNARRC (Schijf et al. 2004). Since 2003, woundfin were stocked annually in the Virgin River each fall. Additional stocking in the spring was initiated in 2008, with the goal of increasing woundfin size and providing the maximum reproductive output possible at the time of stocking. However, since spring stocking was initiated, only about four percent of stocked woundfin were recaptured each year. In response to these low recapture rates, stocking protocols were modified to increase the reproductive viability and contribution of stocked woundfin to wild populations by growing out as many woundfin as possible prior to stocking, and stocking all grow-out woundfin in the spring instead of the fall. Fall stocking will still occur if the numbers of grow-out exceed the space available at Wahweap and SNARRC.

Between 2003 and 2015, the number of woundfin stocked annually into the upper Virgin River mainstem and off channel refuges ranged from approximately 1,700 to 33,000. Approximately 153,000 woundfin were stocked into the mainstem Virgin River with an additional 1,700 woundfin stocked in off channel refuges (Table 3). After 2006, stocking of woundfin in off channel refuge areas was discontinued due to the lack of survival in Zitting and Purgatory ponds.

Prior to stocking, all woundfin are tagged with Visible Implant Elastomer (VIE) tags injected under the skin near the dorsal fin. Tagging allows differentiation between wild and captive stocks. Using recapture data, the distribution and survival of these stocked fish can be estimated through various ongoing native fish monitoring efforts. The results of the dispersal, movement, and survival of stocked woundfin between 2003 and 2005 are described in UDWR publications (Schijf et al. 2004; Fridell and Morvilius 2005a; and Fridell and Morvilius 2005b) and more recent information is summarized below. Unfortunately, the low number of recaptures following stocking often provides little data to evaluate the success of any stocking strategy. For example, between 2007 and 2015, the average recapture rate for stocked woundfin was 3.2 percent (range = 0.5 to 11.0 percent). In 2015, recapture rates for stocked woundfin were 1.6 percent (out of the 24,566 woundfin stocked, only 390 were recaptured between fall 2014 and spring 2015). Of the total woundfin captured during various monitoring projects in 2015, stocked woundfin accounted for only 10 percent (n=390) of the total woundfin captured.

Although these recapture rates make stocking efforts seem unsuccessful, the primary objective of stocking is for reproductive output, not persistence. A better metric to measure stocking success is to evaluate the catch rates of wild and stocked woundfin in spring verses fall. For example, in 2008 (post-2007 fish kill) the only woundfin captures during spring were fish stocked in fall 2007 and spring 2008 (see section 2.3.3.5). By June of 2008, young wild woundfin were captured during various monitoring efforts (i.e., reproduction from stocked woundfin; see section 2.3.1.5) (Bennion 2016, pers. comm.). Therefore, without stocking efforts, woundfin would be extirpated in the upper Virgin River.

In summary, the use of captive woundfin and Virgin River chub to supplement natural populations is an important component of recovery efforts for these species. Monitoring the distribution and survival of stocked woundfin will continue to be a priority. The success of stocked woundfin will continue being evaluated to access the current stocking plan and modify stocking efforts as necessary in order to develop a strategy that will result in the greatest contribution and chance of recovery. Until woundfin populations reach a sustainable level, the continued production and stocking of woundfin will be necessary to ensure the recovery of these native fish. For Virgin River chub, monitoring data show there is some level of reproduction, recruitment, and retention (see section 2.3.1.5). Therefore, while the stocking of Virgin River chub is currently unnecessary, the continued maintenance of broodstock and refuge populations remains important to the recovery of this species because it provides a mechanism for Virgin River chub populations to recover from any potential catastrophic events.

Stocking Accomplishments – Lower Virgin River

In the lower Virgin River (Arizona and Nevada), there are no records of stocking Virgin River chub and only a few records for woundfin stocking. NDOW and AZGFD have stocked woundfin in the lower Virgin River; most of these events occurred prior to 2000. Locations stocked by AZGFD included the Hassayampa River (n=500; February 1972), the Salt River (n=350; March 1972), Sycamore Creek (n=unknown; spring 1972), and the Paria River (n=650; several stockings between 1969 and 1972) (USFWS 1994). None of these stocking events were successful. In the Hassayampa River, woundfin reproduced, but the population was destroyed by flooding in September 1972. In the Salt River, no woundfin were ever captured post-stocking; in Sycamore Creek, no woundfin were collected after 1973 and in the Paria River, no woundfin were captured during surveys in 1974 or 1975. In the lower Virgin River in Nevada, NDOW stocked 33,500 woundfin from SNARRC between 1993 and 2006; 28,500 were stocked between 1993 and 1999, and 5,000 stocked between 2003 and 2006 (USFWS 2006; Chen et al. 2009).

Woundfin stocking was started earlier in the lower river with multiple releases from 1993 to 1998. Unfortunately, stocked woundfin displayed poor retention and survival in the lower Virgin River. However, these stocking efforts occurred below the Bunkerville Diversion, where red shiner were abundant and summer flow conditions were often very low (Golden and Holden 2004). From 1999 through 2001, woundfin were stocked upstream of the Bunkerville Diversion to take advantage of a more constant water supply. In preparation for each stocking event during those years, red shiner were mechanically removed (seining) to reduce predation and competition. Red shiner removal efforts were effective in the short term when conducted under favorable environmental conditions. However, resource managers were unable to demonstrate a long-term effect (Golden and Holden 2004). Woundfin stocked during this period persisted in the study area for as long as 7 to 8 months, and reproduced successfully. Unfortunately, successful recruitment from the reproduced cohort was negligible, which was probably the result of competition and predation from red shiner, as well as similar summer critical limiting factors of low instream flows and high water temperatures as the upper river.

Resource managers concluded that stocking age-0 fish in the fall was more successful than stocking age-1 fish in the spring, but few of the released fish or their offspring were able to survive into the following fall season (Golden and Holden 2004). No woundfin were available for stocking in 2002. In 2003 through 2005, woundfin stocking occurred farther upstream near Beaver Dam Wash. Approximately 2,200 woundfin were stocked in this area in November 2003 and 800 and 250 were stocked in 2004 and 2005, respectively. Monitoring in 2004 and 2005 indicates that a small number of woundfin from the 2003 and 2004 releases survived overwinter and reproduced, but as with prior stocking efforts, very few persisted to the following fall.

Table 2. Summary of Virgin River chub stocking and translocation events between 2002 and 2015, by location and date on the mainstem Virgin River and off channel refuge locations in Utah; the source for each event is also included. In addition to these events, Virgin River chub (n=1,290) were transferred in 1994 from Southwestern Native Aquatic Resource and Recovery Center (SNARRC) and stocked into the upper Virgin River (location unknown).

Location		July 2002	March 2006	Fall 2006	January 2007	November 2007	November 2007	March 2008	March 2009	November 2009	March 2010	November 2010	November 2013	November 2014	December 2014	November 2015	Total
Virgin River Main Stem	Upstream of Ash/La Verkin	-	-	-	-	144	2,609	2,500	-	1,001	-	427	-	-	-	-	6,681
	Downstream of Ash/La Verkin	-	-	-	-	-	-	-	-	1,186	-	-	1,580	-	-	-	2,766
	Above Goulds Wash	-	-	-	-	-	-	-	-	-	1,311	-	-	-	-	-	1,311
	Near Stratton Pond	-	-	-	-	-	-	-	-	-	647	-	-	-	-	-	647
	Hurricane Bridge	-	-	-	-	-	-	-	-	-	553	-	1,150	-	-	-	1,703
	Below Washington Fields Diversion	-	-	-	-	-	-	1,713	-	-	-	-	-	-	-	-	1,713
	Below Johnson Diversion	-	2,138	-	79	-	-	1,100	1,632	889	-	-	435	-	-	2,241	8,514
	Santa Clara River Confluence	-	907	-	-	-	-	-	-	-	-	-	-	-	-	-	907
Off-Channel Refuge	Toquerville Pond	700	-	-	510	-	314	500	-	-	-	-	430	520	-11	-	2,963
	Purgatory Pond	-	-	150	-	-144	422	200	-	232	-	-	215	-	-	-	1,075
	Zitting Pond	-	-	-	-	-	-	300	-	-	-	-	-	-	-	-	300
	Seegmiller Marsh	-	-	-	150	-	-	-	-	-	-	-	-	-	-	-	150
	Willow Canyon Marsh	-	-	-	-	-	-	-	-	-	-	-	215	-	-	-	215
	Riverside Marsh	-	500	-	150	-	-	-	-	-	-	-	-	-	-	-	650
	Springs Estate Marsh	-	500	-	-	-	-	-	-	-	-	-	-	-	-	-	500
	Red Hills Desert Garden Stream	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	11
Total		700	4,045	150	889	0	3,345	6,313	1,632	3,308	2,511	427	4,025	520	0	2,241	30,106
Source		Virgin River	SNARRC	Virgin River	SNARRC	Transfer	Wahweap	SNARRC	Wahweap	Wahweap	SNARRC	Wahweap	Wahweap	Wahweap	Transfer	Wahweap	

Table 3. Summary of woundfin stocking events between 2003 and 2015, by location and date on the mainstem Virgin River and off channel refuge locations in Utah.

Location		November 2003	November 2004	November 2005	November 2006	October 2007	March 2008	October 2008	March 2009	October 2009	March 2010	March 2011	October 2011	March 2012	October 2012	March 2013	October 2013	March 2014	October 2014	March 2015	Total
Virgin River Main Stem	Upstream of Ash/La Verkin	-	-	-	-	965	-	-	-	-	-	-	17,751	-	-	-	-	-	-	-	18,716
	Ash/La Verkin Confluence	1,100	1,200	1,200	2,500	1,708	1,054	3,307	1,197	2,749	975	-	-	-	6,093	-	-	3,203	8,400	8,750	43,436
	Above Quail Creek	1,100	1,200	-	2,500	4,019	1,607	15,711	1,816	3,731	-	706	14,255	3,193	4,916	1,347	6,180	-	3,600	3,816	69,697
	Below Quail Creek	-	-	-	-	-	-	-	-	-	-	-	-	-	3,311	-	-	-	-	-	3,311
	Above Washington Fields Diversion	-	-	-	-	-	-	1,758	-	-	-	349	-	1,864	5,502	1,137	-	-	-	-	10,610
	Below Johnson Diversion	-	-	1,200	-	-	-	1,790	-	-	-	-	-	-	-	-	-	-	-	-	2,990
	Below Webb Hill Barrier	-	-	-	-	-	-	1,852	-	-	-	-	-	-	-	-	-	-	-	-	1,852
Tributary	Ash Creek	-	-	-	250	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	250
	La Verkin Creek	-	-	-	250	-	-	-	-	-	787	-	-	-	-	1,108	-	-	-	-	2,145
Off-Channel Refuge	Zitting Pond	-	350	500	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,350
	Purgatory Pond	-	350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	350
Total		2,200	3,100	2,900	6,000	6,692	2,661	24,418	3,013	6,480	1,762	1,055	32,006	5,057	19,822	3,592	6,180	3,203	12,000	12,566	154,707

2.4 Synthesis

After creation of Lake Mead, woundfin and Virgin River chub had a very limited geographic range, largely confined to the Virgin River mainstem downstream from La Verkin Springs to approximately Halfway Wash. This range has been significantly reduced due to red shiner colonization of the Virgin River as well as decreases of instream flows. Red shiner moved up from Lake Mead rapidly displacing native fish in the Virgin River through competition and direct predation. By the late 1980s, the only portion of woundfin and Virgin River chub historic habitat not occupied by red shiner was the Ash Creek to WFD reach. Although limited numbers of woundfin and Virgin River chub are periodically present in downstream reaches, the only consistently viable populations are present in the 26.3 km (16.3 mi) reach of the Virgin River mainstem between Ash Creek downstream to the WFD.

The limited distribution of woundfin and Virgin River chub populations reduce their ability to respond to stochastic change and makes them particularly vulnerable to catastrophic environmental events. The continued persistence of woundfin and Virgin River chub within this limited distribution threatened by a variety of environmental and human induced factors. Limiting factors include water quality conditions, high water temperatures and clear water associated with low summer flows, predation and competition from nonnative fish, and late summer flow events. Populations are particularly susceptible to episodic spike flows and associated adverse water quality events during late summer low flow and high temperature periods. Runoff and sediment transported by flash events can rapidly reduce dissolved oxygen levels resulting in direct mortality, displacement of fish, and modification of thermal refuge areas. High flow events can also reduce resource and habitat availability through scouring and sediment deposit, and can modify highly productive nursery habitats limiting young-of-year survival and recruitment. In addition, high flow events in late summer can displace a high percentage of larval fish downstream into reaches occupied by red shiner, thus removing or severely limiting annual recruitment.

Woundfin and Virgin River chub population abundance in the Ash Creek to WFD reach are highly variable and fluctuate with water year. Generally, low water years associated drought reduce abundance of woundfin and Virgin River chub populations, and limit successful reproduction and recruitment. Conversely, high water years with extended spring runoff triggers reproduction and the resulting higher summer flows enhance survival and recruitment. Drought periods with below average water years result in depressed population numbers and distribution of woundfin and Virgin River chub. The persistence of woundfin and Virgin River chub during these poor water years is dependent upon ongoing cooperative intensive management actions (e.g., water releases, hatchery propagation, stocking) to maintain populations and enable population response during favorable conditions. Short lived woundfin are highly susceptible to prolonged low flow periods while the longer life span of Virgin River chub allows populations to withstand low water years and respond during good water years. Thus, Virgin River chub are not as susceptible to stochastic and catastrophic events and populations are better able to respond following population declines.

For the last 15 to 20 years, woundfin and Virgin River chub populations remained low during low water years and responded with large reproduction events and recruitment during high water years (e.g., 2005, 2011). However, despite extremely low water years from 2012 through 2015, woundfin populations in the Ash Creek to WFD reach responded with reproduction and recruitment in 2015, resulting in unexpectedly high fall and subsequent spring population numbers. This woundfin population increase was likely the result of intensively managed water releases by the WCWCD to offset high summer water temperature extremes through the pumpback system, increased turbidity, controlled sediment releases, and hatchery stocking. Implementation of these actions through the VRP has stabilized population declines and maintained woundfin and Virgin River chub populations between Ash Creek and WFD. Additional partnerships in the lower Virgin River are needed to assist with rotenone treatments, restoration projects, and fish barriers. The continued cooperation between the WCWCD, local interests, and State and Federal agencies through implementation of the VRP is necessary to maintain woundfin and Virgin River chub populations within their limited geographic range.

3.0 RESULTS

3.1 Recommended classification

_____ Downlist to Threatened
_____ Uplist to Endangered
_____ Delist
__X__ No change is needed

3.2 New recovery priority number

We recommend woundfin and Virgin River chub retain the current Recovery Priority Numbers of 1C and 2C, respectively.

3.3 Listing and reclassification priority number

Not Applicable

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The continued persistence of woundfin and Virgin River chub will require the active management of populations and habitat conditions for the foreseeable future. The VRP has successfully led the implementation of conservation and recovery measures in the upper Virgin River Basin. The VRP provides a vehicle for adaptive broad-based collaborative management between local, state, and Federal interests and resource agencies. The persistence and recovery of woundfin and Virgin River chub is contingent on maintaining communication and cooperation between these interests. Secure funding for the VRP and its signatory partners is imperative to continue recovery actions in the current range of woundfin and Virgin River chub. A similar collaborative management effort needs to extend downstream through the lower Virgin River in Arizona and Nevada.

Human population growth and associated development has escalated in the Virgin River Basin in the last 25 years. The area has rapid population growth and increasing demands on the Virgin River system for water use. Providing instream flows to address high water temperatures and maintain adequate habitat and management of nonnative fishes is critical for the recovery of woundfin and Virgin River chub. Adaptive management is necessary to monitor Virgin River fish status, rapidly implement conservation actions, evaluate population response to those actions, and respond proactively to exploit recovery opportunities.

Based on the current status of woundfin and Virgin River chub, the primary recommendations for recovery include protecting and enhancing woundfin and Virgin River chub populations within their current distribution, and expanding the range of woundfin and Virgin River chub to ensure redundancy and resiliency.

Actions to protect and enhance current woundfin and Virgin River chub populations continue to be implemented through the VRP. Basinwide recovery priorities for woundfin and Virgin River chub are identified and evaluated annually by the Recovery Team. Recovery actions are then implemented by the VRP and lower basin partners. Progress on those actions are reviewed annually and modified as necessary.

The recovery of woundfin and Virgin River chub requires expanding populations and increasing occupied geographic range. Establishing viable populations in the Virgin River downstream of the WFD increases population resiliency and significantly decreases vulnerability. Woundfin and Virgin River chub populations remain vulnerable to both stochastic and catastrophic events within their current limited geographic distribution. Eradication of red shiner and establishing populations downstream of the WFD remains the highest priority for recovery of both species. Although significant progress has been achieved since 2000, it is imperative to continue downstream red shiner eradication to facilitate recovery of woundfin and Virgin River chub. Following red shiner eradication, a fish barrier on the lower Virgin River is critical to prevent recolonization of the Virgin River by red shiner and other nonnative fish from Lake Mead.

In addition, establishing a stable, reproducing woundfin population upstream of the QCD would increase distribution and significantly enhance its ability to withstand drought periods and episodic water quality events. The Virgin River mainstem above the QCD has largely natural flow conditions with protected base flows, unregulated high flow events, sediment transport, and channel forming/habitat maintenance flows. Although, it is unknown whether woundfin will persist in the Virgin River upstream of the QCD, water temperatures during summer baseflow periods are less extreme and are likely to support woundfin survival and recruitment. It may also provide an upstream source capable of supplementing the woundfin population between Ash Creek and WFD. Finally, a stable reproducing woundfin population upstream of the QCD would increase distribution and significantly enhance woundfin populations within their current range. A viable upstream population would achieve redundancy and resiliency by significantly enhancing the species ability to withstand drought periods, episodic water quality events, and other stochastic and catastrophic events.

To ensure redundancy and resiliency, woundfin and Virgin River chub populations need to be reestablished throughout the Virgin River from Johnson Diversion downstream into Arizona and Nevada. First, the downstream eradication of red shiner will need to continue. This will require ongoing cooperation between Recovery Team partners in the upper and lower Virgin River. To ensure eradication success, permanent fish barriers need to be constructed to prevent red shiner recolonization. Once this is accomplished, native fish will need to be reestablished in the lower Virgin River. To facilitate recovery, additional factors limiting recruitment and survival of native fish populations will need to be evaluated and addressed on a reach by reach basis (e.g., nonnative fish, instream temperature and flow, water quality). Conservation actions to remove limiting factors and establish viable populations of woundfin and Virgin River chub must then be implemented (e.g., control smallmouth bass and red shiner, mitigate high instream temperatures, increase instream flows, protect riparian habitat). In addition, we recommend evaluating the status of the Muddy River population of Virgin River chub and, if warranted, including the population into a revised recovery strategy and criteria.

Recommendations to address population resiliency, redundancy, and representation are summarized below for woundfin (Table 4) and Virgin River chub (Table 5).

Table 4. Recommendations for woundfin resiliency, redundancy, and representation in regards to needs, current condition, and future condition and viability.

3 R's	Species Needs	Current Condition	Future Conditions and Viability
Resiliency – Individuals: Conditions necessary to recruit to adult populations (survival, growth, reproduction)	a) Sandy run habitat b) Adequate instream flow with summer pulse events c) Suitable water quality (e.g., temperature, dissolved oxygen, turbidity) d) Eliminate competition and predation from nonnative species	a) Habitat availability is dependent on water year and sediment management. b) Natural flows and water management provide some instream flow and summer pulse events. c) Water quality limits distribution and abundance during summer months. d) Red shiner occupy/dominate population in reaches from Stateline barrier downstream. Nonnative vegetation also impacts normal river processes.	a) Continue sediment management, riparian restoration, and floodplain protection. b) Identify areas where additional water management efforts are required. c) Improve summer water quality conditions by managing instream flows. d) Remove red shiner downstream from Stateline barrier through Arizona and Nevada. Remove nonnative vegetation throughout the Virgin River basin.
Resiliency – Population: Large populations to withstand stochastic events	a) Self-sustaining populations	a) Consistently reproducing population only occurs in upper Virgin River between Ash Creek and WFD. Downstream reaches are dominated by red shiner.	a) Eradicate red shiner from the Virgin River Basin and expand distribution downstream through Arizona and Nevada to increase resiliency, redundancy, and genetic viability.
Redundancy – Species: Number and distribution of populations to withstand catastrophic events	a) Multiple highly resilient populations in the upper Virgin River (Utah) and lower Virgin River (Arizona and Nevada) b) Maintain propagation and refuge populations at hatcheries	a) The population in the upper Virgin River between Ash Creek and WFD requires supplementation and intensive management. Sporadic distribution of individuals occurs in the lower Virgin River with limited reproduction. b) Propagation and refuge populations are maintained at Southwestern Native Aquatic Resources and Recovery Center.	a) Expand distribution upstream of Quail Creek Diversion and extend distribution downstream through Arizona and Nevada. b) Maintain genetically diverse refuge populations to ensure recovery from catastrophic events.
Representation – Species: Genetic and ecological diversity to maintain adaptive potential	a) Genetically diverse populations b) Natural river processes and diversity of habitat/substrate	a) High levels of genetic variation are maintained. b) River processes are affected by drought and nonnative vegetation.	a) Supplement hatchery broodstocks to maintain genetic variability. b) Restore riparian habitat rangewide to increase natural river function, complexity, and productivity. Encourage stewardship among communities through outreach efforts.

Table 5. Recommendations for Virgin River chub resiliency, redundancy, and representation in regards to needs, current condition, and future condition and viability.

3 R's	Species Needs	Current Condition	Future Conditions and Viability
Resiliency – Individuals: Conditions necessary to recruit to adult populations (survival, growth, reproduction)	a) Deep habitat with cover b) Adequate instream flow with summer pulse events c) Suitable water quality (e.g., temperature, dissolved oxygen, turbidity) d) Eliminate competition and predation from nonnative species	a) Habitat availability is dependent on water year and sediment management. b) Natural flows and water management provide some instream flow and summer pulse events. c) Water quality limits distribution and abundance during summer months. d) Red shiner occupy/dominate population in reaches from Stateline barrier downstream. Nonnative vegetation also impacts normal river processes.	a) Continue sediment management, riparian restoration, and floodplain protection. b) Identify areas where additional water management efforts are required. c) Improve summer water quality conditions by managing instream flows. d) Remove red shiner downstream from Stateline Barrier through Arizona and Nevada. Remove nonnative vegetation throughout the Virgin River Basin.
Resiliency – Population: Large populations to withstand stochastic events	a) Self-sustaining populations	a) Reproducing populations occur in the upper Virgin River between Ash Creek and WFD and in the lower Virgin River downstream of Littlefield Springs. Reaches downstream of Stateline Barrier are dominated by red shiner.	a) Eradicate red shiner from the Virgin River Basin and expand distribution downstream through Arizona and Nevada to increase resiliency, redundancy, and genetic viability.
Redundancy – Species: Number and distribution of populations to withstand catastrophic events	a) Multiple highly resilient populations in the upper Virgin River (Utah) and lower Virgin River (Arizona and Nevada) b) Maintain refuge populations at hatcheries	a) A self-sustaining population exists in the upper Virgin River between Ash Creek and WFD. A small adult population continues to persist in the lower Virgin River. b) A refuge population maintained at Wahweap State Fish Hatchery.	a) Extend distribution downstream through Arizona and Nevada. b) Evaluate the status of the Muddy River population of Virgin River chub and include the population in a revised Recovery Plan if necessary. c) Maintain genetically diverse refuge populations to ensure recovery from catastrophic events.
Representation – Species: Genetic and ecological diversity to maintain adaptive potential	a) Genetically diverse populations b) Natural river processes and diversity of habitat/substrate	a) High levels of genetic variation are maintained. b) River processes are affected by drought and nonnative vegetation.	a) Supplement hatchery broodstocks to maintain genetic variability. b) Restore riparian habitat rangewide to increase natural river function, complexity, and productivity. Encourage stewardship among communities through outreach efforts.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW

Virgin River Chub (*Gila seminuda*) and Woundfin (*Plagopterus argentissimus*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist:
____ Extinction
____ Recovery
____ Original data for classification in error
_X_ No change is needed

Appropriate Listing/Reclassification Priority Number, if applicable:
No change from 2C (Virgin River chub) or 1C (woundfin).

Recommendations for Future Actions:

Address the status of the Muddy River population of Virgin River chub

Field Office Approval:

LAURA ROMIN Digitally signed by LAURA ROMIN Date: 2020.06.05 07:58:54 -06'00'

Approve: ______________________________ Date: ____________________

Laura Romin
Acting Field Office Supervisor
Utah Ecological Services Field Office,
U.S Fish and Wildlife Service, Interior Region 5 and 7

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

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Appendix A. Summary of species recovery priority numbers including degree of threat, recovery potential, taxonomy, priority, and conflict (adapted from USFWS 2008a).

Degree of Threat	Recovery Potential	Taxonomy	Priority	Conflict
High	High	Monotypic Genus	1	1C
		Species	2	2C
		Subspecies / DPS	3	3C
	Low	Monotypic Genus	4	4C
		Species	5	5C
		Subspecies / DPS	6	6C
Moderate	High	Monotypic Genus	7	7C
		Species	8	8C
		Subspecies / DPS	9	9C
	Low	Monotypic Genus	10	10C
		Species	11	11C
		Subspecies / DPS	12	12C
Low	High	Monotypic Genus	13	13C
		Species	14	14C
		Subspecies / DPS	15	15C
	Low	Monotypic Genus	16	16C
		Species	17	17C
		Subspecies / DPS	18	18C

Appendix B. Summary of woundfin and Virgin River chub catch rates (number of fish per seine haul), natural logarithm of catch rate (*ln*+1), and number captured (n=) during fall (September) population response station monitoring at the following stations: Above Washington Fields Diversion (AWFD), Quail Creek (QC), and Ash/La Verkin (AL), 2003 to 2015. Note: October data was used for all stations in 2005 and 2011, since stations were not monitored in September.

	Woundfin										Virgin River Chub									
YEAR	AWFD (n=)	AWFD (CPE)	AWFD (*ln*+1)	QC (n=)	QC (CPE)	QC (*ln*+1)	AL (n=)	AL (CPE)	AL (*ln*+1)	TOTAL (n=)	AWFD (n=)	AWFD (CPE)	AWFD (*ln*+1)	QC (n=)	QC (CPE)	QC (*ln*+1)	AL (n=)	AL (CPE)	AL (*ln*+1)	TOTAL (n=)
2003	21	0.42	0.35	1	0.02	0.02	0	0.00	0.00	22	0	0.00	0.00	3	0.06	0.06	13	0.26	0.23	16
2004	116	2.32	1.20	11	0.22	0.20	13	0.26	0.23	140	1	0.02	0.02	24	0.48	0.39	134	2.68	1.30	159
2005	928	18.56	2.97	655	13.10	2.65	196	3.92	1.59	1,779	174	3.48	1.50	664	13.28	2.66	744	14.88	2.77	1,582
2006	3	0.06	0.06	2	0.04	0.04	5	0.10	0.10	10	26	0.52	0.42	48	0.96	0.67	75	1.50	0.92	149
2007	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0	0.00	0.00	0	0.00	0.00	1	0.02	0.02	1
2008	0	0.00	0.00	15	0.30	0.26	1	0.02	0.02	16	0	0.00	0.00	3	0.06	0.06	111	2.22	1.17	114
2009	0	0.00	0.00	1	0.02	0.02	0	0.00	0.00	1	0	0.00	0.00	8	0.16	0.15	16	0.32	0.28	24
2010	3	0.06	0.06	0	0.00	0.00	0	0.00	0.00	3	0	0.00	0.00	3	0.06	0.06	9	0.18	0.17	12
2011	208	4.20	1.65	22	0.44	0.36	0	0.00	0.00	230	175	3.50	1.50	410	8.20	2.22	237	4.70	1.74	822
2012	1	0.02	0.02	0	0.00	0.00	1	0.02	0.02	2	69	1.38	0.87	45	0.90	0.64	43	0.86	0.62	157
2013	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	15	0.30	0.26	13	0.26	0.23	8	0.16	0.15	36
2014	2	0.04	0.04	7	0.14	0.13	1	0.02	0.02	10	7	0.14	0.13	1	0.02	0.02	12	0.24	0.22	20
2015	31	0.62	0.48	13	0.26	0.23	3	0.06	0.06	47	0	0.00	0.00	3	0.06	0.06	18	0.36	0.31	21

Appendix C. Summary of woundfin and Virgin River chub captured (n=), catch rates (number of fish per seine haul), and natural logarithm of catch rate (*ln*+1) for fall full pass distribution monitoring, 2002 to 2015.

Season	Year	Woundfin			Virgin River Chub		
		n=	Catch Rate	*ln*+1	n=	Catch Rate	*ln*+1
Fall	2002	109	0.063	0.06	211	0.122	0.12
Fall	2003	115	0.062	0.06	436	0.236	0.21
Fall	2004	2676	1.094	0.74	5528	2.260	1.18
Fall	2005	40120	15.820	2.82	47550	18.750	2.98
Fall	2006	596	0.165	0.15	2872	0.796	0.59
Fall	2007	0	0.000	0.00	23	0.007	0.01
Fall	2008	428	0.138	0.13	8457	2.721	1.31
Fall	2009	272	0.068	0.07	516	0.130	0.12
Fall	2010	352	0.085	0.08	485	0.117	0.11
Fall	2011	4186	1.059	0.72	30746	7.780	2.17
Fall	2012	10	0.002	0.00	2487	0.519	0.42
Fall	2013	0	0.000	0.00	1317	0.281	0.25
Fall	2014	657	0.162	0.15	367	0.090	0.09
Fall	2015	2423	0.541	0.43	930	0.208	0.19

Appendix D. Summary of Virgin River chub monitoring for all stations combined by year including number of hoop nets (n=), Virgin River chub captured (n=), trap hours, catch rate (number of fish per trap hour), and natural logarithm of catch rate (*ln*+1), 2006 to 2015.

Year	**Hoop Nets (n=)**	**Virgin River Chub (n=)**	**Trap Hours**	**Catch Rate**	**Catch Rate (*ln*+1)**
2006	71	1,774	1345.3	1.319	0.841
2007	74	155	1409.1	0.110	0.104
2008	75	508	1462.5	0.347	0.298
2009	72	261	1484.7	0.176	0.162
2010	65	254	1258.2	0.202	0.184
2011	70	582	1372.0	0.424	0.354
2012	74	379	1474.2	0.257	0.229
2013	67	221	1358.8	0.163	0.151
2014	72	226	1486.8	0.152	0.142
2015	72	223	1476.0	0.151	0.141

Appendix E. Summary of Virgin River Chub captured during Recovery Team monitoring for Ash Creek station, including date, season, year, number of sites monitored (seine units), number of seine hauls, area monitored (m^2), Virgin River Chub captured (n=), Virgin River Chub catch per effort (CPE; number of fish divided by number of seine hauls), and natural logarithm of Virgin River Chub CPE, 1976 to 2015.

Date	Season	Year	Seine Units	Seine Hauls	Sample Area (m^2)	Virgin River Chub (n=)	Virgin River Chub (CPE)	Virgin River Chub CPE (*ln+1*)
1976*	fall	1976						
9/15/1977	fall	1977	3	12	47.0	1	0.08	0.08
9/28/1978	fall	1978	1	5	195.0	7	1.40	0.88
10/17/1979	fall	1979	3	11	30.0	5	0.45	0.37
1980*	fall	1980						
1981*	fall	1981						
1982*	fall	1982						
9/27/1983	fall	1983	4	10	40.0	0	0.00	0.00
10/5/1984	fall	1984	5	32	40.0	3	0.09	0.09
9/10/1985	fall	1985	10	25	40.0	0	0.00	0.00
10/16/1986	fall	1986	10	36	40.0	21	0.58	0.46
10/14/1987	fall	1987	11	21	40.0	0	0.00	0.00
10/30/1988	fall	1988	10	37	40.0	0	0.00	0.00
10/11/1989	fall	1989	10	33	40.0	0	0.00	0.00
10/13/1990[E]	fall	1990	20	32	40.0	5	0.16	0.15
11/4/1991	fall	1991	10	27	40.0	10	0.37	0.32
9/22/1992[E]	fall	1992	10	32	51.4	0	0.00	0.00
9/28/1993[E]	fall	1993	11	32	40.0	104	3.25	1.45
9/26/1994	fall	1994	12	41	40.0	16	0.39	0.33
10/2/1995	fall	1995	11	36	40.0	2	0.06	0.05
9/25/1996	fall	1996	14	40	46.9	24	0.60	0.47
9/30/1997	fall	1997	12	39	50.0	0	0.00	0.00
9/29/1998	fall	1998	12	42	48.8	39	0.93	0.66
10/4/1999	fall	1999	14	44	50.0	30	0.68	0.52
10/3/2000	fall	2000	8	32	50.0	19	0.59	0.47
10/3/2001	fall	2001	14	35	50.0	2	0.06	0.06
9/24/2002	fall	2002	10	34	50.0	3	0.09	0.08

* Station was not monitored

** No data recorded

Appendix E. Continued.

Date	Season	Year	Seine Units	Seine Hauls	Sample Area (m^2)	Virgin River Chub (n=)	Virgin River Chub (CPE)	Virgin River Chub CPE (*ln+1*)
9/30/2003	fall	2003	10	47	50.0	41	0.87	0.63
10/6/2004	fall	2004	10	42	50.0	16	0.38	0.32
9/28/2005	fall	2005	10	47	50.0	182	3.87	1.58
9/25/2006	fall	2006	10	39	**	22	0.56	0.45
9/25/2007	fall	2007	20	30	**	2	0.07	0.06
9/29/2008	fall	2008	14	44	28.3	106	2.41	1.23
10/1/2009	fall	2009	20	26	50.0	0	0.00	0.00
9/28/2010	fall	2010	20	32	50.0	2	0.06	0.06
8/29/2011	fall	2011	10	39	50.0	578	14.82	2.76
9/24/2012	fall	2012	20	37	50.0	24	0.65	0.50
10/23/2013	fall	2013	20	22	50.0	1	0.05	0.04
10/24/2014	fall	2014	20	27	50.0	12	0.44	0.37
10/5/2015	fall	2015	16	40	50.0	8	0.20	0.18

Appendix F. Summary of woundfin captured during Recovery Team monitoring for Twin Bridges station, including date, season, year, number of sites monitored (seine units), number of seine hauls, area monitored (m^2), woundfin captured (n=), woundfin catch per effort (CPE; number of fish divided by number of seine hauls), and natural logarithm of woundfin CPE, 1978 to 2015.

Date	Season	Year	Seine Units	Seine Hauls	Sample Area (m^2)	Woundfin (n=)	Woundfin (CPE)	Woundfin CPE (*ln+1*)
9/28/1978	fall	1978	5	13	39.3	9	0.69	0.53
10/18/1979	fall	1979	7	10	30.0	1	0.10	0.10
10/22/1980	fall	1980	3	11	40.0	237	21.55	3.12
10/30/1981	fall	1981	8	29	30.0	204	7.03	2.08
9/22/1982	fall	1982	4	12	30.0	302	25.17	3.26
9/27/1983	fall	1983	3	16	29.0	230	14.38	2.73
10/5/1984	fall	1984	8	28	30.0	102	3.64	1.54
10/9/1985	fall	1985	7	24	30.0	115	4.79	1.76
10/15/1986	fall	1986	10	34	40.0	72	2.12	1.14
10/14/1987	fall	1987	10	40	40.0	12	0.30	0.26
1988*	fall	1988						
10/12/1989[E]	fall	1989	11	35	40.0	0	0.00	0.00
10/13/1990[E]	fall	1990	28	35	40.0	5	0.14	0.13
1991*	fall	1991						
1992*	fall	1992						
10/26/1993	fall	1993	11	36	41.8	6	0.17	0.15
9/26/1994	fall	1994	10	34	26.5	0	0.00	0.00
10/4/1995	fall	1995	10	36	50.0	42	1.17	0.77
10/1/1996	fall	1996	14	62	41.6	1	0.02	0.02
10/2/1997	fall	1997	11	46	40.5	1	0.02	0.02
10/1/1998	fall	1998	13	44	53.9	17	0.39	0.33
10/6/1999	fall	1999	11	58	50.0	18	0.31	0.27
10/5/2000	fall	2000	10	50	50.0	0	0.00	0.00
10/2/2001	fall	2001	9	58	50.0	0	0.00	0.00
9/23/2002	fall	2002	10	41	51.3	1	0.02	0.02
9/29/2003	fall	2003	10	38	50.0	0	0.00	0.00
10/4/2004	fall	2004	10	60	50.0	0	0.00	0.00

* Station not monitored

[E] Seine haul data not recorded used average number seine hauls between 1978 to 2015 as an estimate to fill data gaps

Appendix F. Continued.

Date	Season	Year	Seine Units	Seine Hauls	Sample Area (m^2)	Woundfin (n=)	Woundfin (CPE)	Woundfin CPE (*ln+1*)
9/28/2005	fall	2005	15	65	50.0	0	0.00	0.00
9/22/2006	fall	2006	21	37	49.5	2	0.05	0.05
9/25/2007	fall	2007	20	21	50.0	0	0.00	0.00
9/29/2008	fall	2008	20	20	50.0	0	0.00	0.00
9/30/2009	fall	2009	20	38	38.3	0	0.00	0.00
9/28/2010	fall	2010	20	27	50.0	0	0.00	0.00
8/31/2011	fall	2011	14	38	50.0	0	0.00	0.00
9/25/2012	fall	2012	20	29	50.0	0	0.00	0.00
10/23/2013	fall	2013	20	20	50.0	0	0.00	0.00
10/15/2014	fall	2014	20	40	50.0	0	0.00	0.00
10/5/2015	fall	2015	10	31	50.0	0	0.00	0.00

* Station not monitored

[E] Seine haul data not recorded used average number seine hauls between 1978 to 2015 as an estimate to fill data gaps

Appendix G. Summary of woundfin captured during Recovery Team monitoring for Beaver Dam Wash station, including date, season, year, number of sites monitored (seine units), number of seine hauls, area monitored (m^2), woundfin captured (n=), woundfin catch per effort (CPE; number of fish divided by number of seine hauls), and natural logarithm of woundfin CPE, 1976 to 2015. Note: Beaver Dam Wash station was not monitored in fall 1997 and fall 2014, substituted with Riverside station in fall 1997 and Mesquite Diversion station in fall 2014.

Date	Season	Year	Seine Units	Seine Hauls	Sample Area (m^2)	Woundfin (n=)	Woundfin (CPE)	Woundfin CPE (*ln+1*)
9/29/1976^E	fall	1976	4	38	40.0	91	2.39	1.22
8/30/1977^E	fall	1977	7	38	36.0	94	2.47	1.25
9/28/1978	fall	1978	4	13	43.1	145	11.15	2.50
10/17/1979	fall	1979	3	12	30.0	270	22.50	3.16
10/22/1980	fall	1980	5	16	30.0	128	8.00	2.20
10/29/1981	fall	1981	5	37	42.0	103	2.78	1.33
9/21/1982	fall	1982	15	87	42.0	326	3.75	1.56
9/27/1983	fall	1983	6	29	25.5	73	2.52	1.26
10/5/1984	fall	1984	9	41	21.0	87	2.12	1.14
10/9/1985	fall	1985	4	20	30.0	15	0.75	0.56
10/15/1986	fall	1986	11	46	40.0	111	2.41	1.23
10/14/1987	fall	1987	10	42	40.0	8	0.19	0.17
10/30/1988	fall	1988	10	37	40.0	0	0.00	0.00
10/11/1989	fall	1989	10	42	40.0	0	0.00	0.00
10/15/1990^E	fall	1990	23	38	40.0	0	0.00	0.00
11/5/1991	fall	1991	10	30	40.0	0	0.00	0.00
9/24/1992	fall	1992	10	33	32.1	0	0.00	0.00
9/28/1993	fall	1993	10	33	35.4	0	0.00	0.00
9/27/1994	fall	1994	10	15	38.7	0	0.00	0.00
10/4/1995^E	fall	1995	10	38	43.8	0	0.00	0.00
9/30/1996^E	fall	1996	10	38	46.4	0	0.00	0.00
9/30/1997^E	fall	1997	10	38	57.6	0	0.00	0.00
9/29/1998^E	fall	1998	11	38	463.0	0	0.00	0.00
10/5/1999^E	fall	1999	10	38	71.4	0	0.00	0.00
10/5/2000^E	fall	2000	17	38	181.1	9	0.24	0.21
10/3/2001^E	fall	2001	13	38	53.7	0	0.00	0.00
9/23/2002	fall	2002	7	10	35.8	0	0.00	0.00

* Station was not monitored
** No data recorded
^E Seine haul data not recorded used average number seine hauls between 1976 and 2015 as an estimate to fill data gaps

Appendix G. Continued.

Date	Season	Year	Seine Units	Seine Hauls	Sample Area (m^2)	Woundfin (n=)	Woundfin (CPE)	Woundfin CPE (*ln+1*)
9/29/2003	fall	2003	13	14	75.7	0	0.00	0.00
10/5/2004	fall	2004	12	11	50.0	0	0.00	0.00
10/31/2005[E]	fall	2005	10	38	50.0	1	0.03	0.03
10/17/2006[E]	fall	2006	21	38	50.0	0	0.00	0.00
10/9/2007[E]	fall	2007	11	38	50.0	0	0.00	0.00
10/1/2008[E]	fall	2008	10	38	50.0	0	0.00	0.00
9/8/2009[E]	fall	2009	10	38	50.0	0	0.00	0.00
2010*	fall	2010						
9/18-24/2011	fall	2011	**	83	50.0	2	0.02	0.02
9/9-15/2012	fall	2012	**	84	50.0	0	0.00	0.00
9/1-7/2013	fall	2013	**	87	50.0	0	0.00	0.00
10/20/2014	fall	2014	10	38	50.0	0	0.00	0.00
11/5/2015	fall	2015	11	48	50.0	0	0.00	0.00

* Station was not monitored

** No data recorded

[E] Seine haul data not recorded used average number seine hauls between 1976 and 2015 as an estimate to fill data gaps

Appendix H. Summary of population response station mapping by station including year, month, volume (m^3), and percent of the total volume by habitat for the following stations: Above Washington Fields Diversion (AWFD), Below Quail Creek (BQC), Above Quail Creek (AQC), and Ash/La Verkin (AL), 2003 to 2015.

Year	Month	Station	Run		Riffle		Pool		Backwater		Total	
			Volume (m^3)	%	Volume (m^3)	%	Volume (m^3)	%	Volume (m^3)	%	Volume (m^3)	%
2003	June	AWFD	5,570	78	568	8	1,017	14	0	0.00	7,155	100
2004	May	AWFD	6,759	77	860	10	1,115	13	0	0.01	8,735	100
2005	June	AWFD	33,300	90	1,982	5	1,650	4	34	0.09	36,966	100
2006	May	AWFD	12,524	67	368	2	5,731	31	103	0.55	18,727	100
2007	June	AWFD	10,688	74	343	2	3,452	24	1	0.01	14,484	100
2008	June	AWFD	8,244	86	515	5	809	8	4	0.04	9,572	100
2009	June	AWFD	8,368	85	348	4	1,082	11	1	0.01	9,800	100
2010	June	AWFD	12,435	88	875	6	746	5	7	0.05	14,063	100
2011	July	AWFD	29,170	86	1,477	4	3,193	9	89	0.26	33,930	100
2012	June	AWFD	14,531	81	533	3	2,916	16	20	0.11	18,000	100
2013	June	AWFD	11,097	73	736	5	3,397	22	19	0.13	15,250	100
2014	June	AWFD	7,382	86	483	6	708	8	40	0.47	8,613	100
2015	January	AWFD	8,889	97	0	0	280	3	0	0.00	9,170	100
2003	June	BQC	2,639	64	1,016	25	468	11	0	0.00	4,123	100
2004	May	BQC	3,628	67	1,466	27	344	6	0	0.00	5,438	100
2005	June	BQC	9,026	64	1,561	11	3,503	25	49	0.35	14,140	100
2006	May	BQC	6,802	73	421	4	2,076	22	79	0.84	9,378	100
2007	June	BQC	5,074	54	613	6	3,731	40	14	0.15	9,432	100
2008	June	BQC	4,339	71	515	8	1,292	21	2	0.03	6,148	100
2009	June	BQC	1,275	45	1,023	36	530	19	0	0.00	2,828	100
2010	June	BQC	2,494	74	269	8	596	18	0	0.00	3,359	100
2011	July	BQC	6,577	47	1,973	14	5,540	39	14	0.10	14,103	100
2012	June	BQC	5,868	75	480	6	1,500	19	0	0.01	7,849	100
2013	June	BQC	3,987	60	487	7	2,189	33	0	0.00	6,662	100
2014	June	BQC	2,869	74	311	8	703	18	0	0.01	3,883	100
2015	January	BQC	3,368	85	268	7	288	7	18	0.45	3,942	100
2003	June	AQC	1,885	62	740	24	415	14	24	0.80	3,065	100
2004	May	AQC	3,273	59	1,059	19	1,224	22	31	0.55	5,586	100
2005	June	AQC	10,393	42	5,234	21	9,159	37	0	0.00	24,786	100
2006	May	AQC	6,551	40	961	6	8,874	54	8	0.05	16,394	100
2007	June	AQC	4,083	44	1,285	14	3,982	43	13	0.14	9,363	100
2008	June	AQC	4,719	64	1,625	22	1,075	14	6	0.08	7,425	100
2009	June	AQC	5,128	59	1,263	15	2,256	26	0	0.00	8,647	100
2010	June	AQC	6,665	56	2,378	20	2,914	24	0	0.00	11,957	100
2011	July	AQC	5,926	44	1,909	14	5,695	42	30	0.22	13,560	100
2012	June	AQC	4,527	40	1,223	11	5,566	49	30	0.27	11,346	100
2013	June	AQC	3,944	40	1,183	12	4,686	48	0	0.00	9,813	100
2014	June	AQC	3,089	80	410	11	372	10	2	0.06	3,873	100
2015	January	AQC	2,988	78	316	8	523	14	0	0.00	3,826	100
2003	June	AL	3,184	46	1,590	23	2,179	31	37	0.52	6,989	100
2004	May	AL	5,916	56	3,189	30	1,548	15	0	0.00	10,652	100
2005	June	AL	17,276	48	11,041	30	7,874	22	15	0.04	36,206	100
2006	May	AL	9,052	47	2,195	11	8,133	42	8	0.04	19,388	100
2007	June	AL	6,946	51	3,056	22	3,577	26	15	0.11	13,594	100
2008	June	AL	8,397	57	3,113	21	3,141	21	14	0.10	14,665	100
2009	June	AL	5,668	47	1,785	15	4,663	38	73	0.60	12,189	100
2010	June	AL	10,860	55	4,392	22	4,587	23	38	0.19	19,877	100
2011	July	AL	12,772	52	3,959	16	7,664	31	25	0.10	24,419	100
2012	June	AL	5,037	75	1,096	16	482	7	86	1.28	6,701	100
2013	June	AL	9,207	64	2,080	14	3,058	21	10	0.07	14,355	100
2014	June	AL	6,368	69	1,722	19	1,170	13	0	0.00	9,260	100
2015	January	AL	5,764	65	1,643	19	1,397	16	17	0.19	8,821	100