THE VIRGIN RIVER FISHES

Woundfin
(*Plagopterus argentissimus*)

Virgin River chub
(*Gila seminuda*)

5-Year Review:
Summary and Evaluation

March 2008

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*)

TABLE OF CONTENTS

GENERAL INFORMATION 1
PEER REVIEWERS 1
METHODOLOGY USED TO COMPLETE THE REVIEW 1
BACKGROUND 2
Federal Register Notice Announcing Initiation Of This Review 2
Listing History 2
Associated Rulemakings 3
Review History 4
Species' Recovery Priority Number At Start Of 5-Year Review 4
Recovery Plan 5
REVIEW ANALYSIS 5
APPLICATION OF THE 1996 DISTINCT POPULATION SEGMENT POLICY 5
Is The Species Under Review A Vertebrate? 5
Is The Species Under Review Listed As A DPS? 5
Is There Relevant New Information For This Species Regarding The Application Of The DPS Policy? 5
RECOVERY CRITERIA 6
Does The Species Have A Final, Approved Recovery Plan Containing Objective, Measurable Criteria? 6
Adequacy Of Recovery Criteria 6
Do The Recovery Criteria Reflect The Best Available And Most Up-To Date Information On The Biology Of The Species And Its Habitat? 6
Are All Of The 5 Listing Factors That Are Relevant To The Species Addressed In The Recovery Criteria? 6
List The Recovery Criteria As They Appear In The Recovery Plan 6
UPDATED INFORMATION AND CURRENT SPECIES STATUS 12
Biology and Habitat 12
New Information On The Species' Biology And Life History 12
Abundance, Population Trends, Demographic Features, Or Demographic Trends 13
Genetics, Genetic Variation, Or Trends In Genetic Variation 29
Taxonomic Classification Or Changes In Nomenclature 30
Spatial Distribution, Trends In Spatial Distribution 31
Habitat Or Ecosystem Conditions 31
Five-Factor Analysis 32
Present Or Threatened Destruction, Modification Or Curtailment Of Its Habitat Or Range 32
Overutilization For Commercial, Recreational, Scientific, Or Educational Purposes 37
Disease Or Predation 37
Inadequacy Of Existing Regulatory Mechanisms 40
Other Natural Or Manmade Factors Affecting Its Continued Existence 44
SYNTHESIS 46
RESULTS 47
RECOMMENDED CLASSIFICATION 47
NEW RECOVERY PRIORITY NUMBER 47
LISTING AND RECLASSIFICATION PRIORITY NUMBER 48
RECOMMENDATIONS FOR FUTURE ACTIONS 48
REFERENCES 49
PERSONAL COMMUNICATIONS 56
APPENDIX A 58

5-YEAR REVIEW
Woundfin / *Plagopterus argentissimus*
Virgin River Chub / *Gila seminuda*

1.0 GENERAL INFORMATION

1.1 PEER REVIEWERS

Lead Regional Office: Seth Willey, Region 6 Endangered Species Regional Recovery Coordinator, 303-236-4257.

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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 are then, under section 4(c)(2)(B) and the provisions of subsections (a) and (b), to 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). This review, along with that for four other species, was initiated via *Federal Register* notice, in 2006 (71 FR 17900, April 7, 2006). The public comment period was open until June 6, 2006. We received a letter from the State of Arizona Game and Fish Department on June 5, 2006, which transmitted the following: a) that agency's recommendation to not change the listing status of the Virgin River chub and woundfin; b) agency personnel's notes from recent Recovery Team meetings; c) a summary of recent conservation actions; and d) a reprint of a peer-reviewed journal article that summarized historical changes in the fish community of the Virgin-Moapa River system (Holden et al. 2005). We also received a letter from the Assistant Field Manager of Bureau of Land Management – Price Field office, on May 5, 2006, which indicated they had no new information on these two species. This review was drafted by biologists from the Utah Ecological Services Field Office with assistance from biologists in Field Offices in Arizona and Nevada. On January 24, 2007, a meeting of the Virgin River Fishes Recovery Team (Recovery Team) was convened in St. George, Utah, to discuss appropriate data sources for the population distribution and abundance review (Sect. 2.3.1.2) and perceived threats (Sect. 2.3.2). Portions of an early draft were distributed to the Recovery Team and discussed at a meeting in St. George, Utah, on

April 27, 2007. Comments received from Recovery Team members and from U.S. Fish and Wildlife Service (USFWS) personnel in the cooperating Field Offices were incorporated in a draft submitted for peer review on July 18, 2007. The final of four peer reviews was received via electronic mail on August 20, 2007. Mr. Michael Golden, Utah Division of Wildlife Resources – Saint George Field Office accessed the Virgin River database, analyzed the long term catch data and provided all abundance graphics (Figures 2-9) used in this review. He deserves special thanks.

1.3 BACKGROUND

1.3.1 Federal Register Notice Announcing Initiation Of This Review

71 FR 17900, April 7, 2006.

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 Virgin River chub was first recognized as a species intermediate between the roundtail chub (*Gila robusta*) and the bonytail (*Gila elegans*). Later authors treated this chub as a subspecies of *G. robusta*. Holden and Stalnaker (1970) showed that the subspecific name, *seminuda*, should refer only to the chub found in the Virgin River, and that other specimens from other localities represented other subspecies of *Gila robusta*. Therefore, the Virgin River chub was listed as, *Gila robusta seminuda*. The USFWS later formally recognized (65 FR 4140, January 26, 2000) the work of Demarias et al. (1992), which indicated that the Virgin River chub warranted full species status (i.e., *Gila seminude*).

At the time of listing, the USFWS recognized that a closely related species was found in the Moapa (or Muddy) River in Nevada. The Muddy River was originally a tributary of the Virgin River prior to their confluence being inundated by Lake Mead. The Muddy River form of chub was not listed with the Virigin River chub (54 FR 35305, August 24, 1989). However, Demarias et al. (1992) concluded that the chub found in the Muddy River also was *Gila seminuda*, although it was "distinctive." The population of *Gila seminuda* that resides in the Muddy River in Nevada is not listed (refer to sections 1.3.3 and 2.3.1.4. below).

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 - Proposal withdrawn due to the 1978 amendments to ESA, which required proposals to be withdrawn if not finalized within 2 years.

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

45 FR 64853, September 30, 1980 – Proposal 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. Applies 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 to 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 the analysis of economic and other impacts.

On March 18, 1994, the U.S. District Court of Colorado orders the USFWS to designate critical habitat for the woundfin, the Virgin River chub, and the Virgin spinedace (if it is listed).

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

60 FR 17296, April 5, 1995 – Proposed rule to designate critical habitat for all three fish.

On April 11, 1995, the USFWS signs 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 Muddy River. The USFWS abandoned this action when Congress enacts a temporary (Fiscal Year 1995 and part of Fiscal Year 1996) moratorium on final listing actions.

61 FR 4401, February 6, 1996 – Withdraw the proposal to list spinedace and to 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 determines that designation of critical habitat is a low priority as listing actions became backlogged during the moratorium of Fiscal Year 1995 and 1996.

On August 27, 1999, the U.S. District Court of Colorado orders USFWS 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, the USFWS recognizes full species status for the Virgin River chub (*Gila seminuda*).

1.3.4 Review History

Historic 5-year reviews for all listed species have been initiated by the USFWS Washington, D.C., office (44 FR 29566, May 21, 1979, 56 FR 56882, November 6, 1991).

1.3.5 Species' Recovery Priority Number At Start Of 5-Year Review

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

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

The Virgin River chub currently 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 the species is in conflict with construction or other development or other forms of economic activity.

1.3.6 Recovery Plan

Name of plan: Virgin River Fishes Recovery Plan (referred to as Recovery Plan throughout this status review)
(see: http://ecos.fws.gov/tess_public/SpeciesReport.do)

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 Is The Species Under Review A Vertebrate?

_x_ Yes
___ No

2.1.2 Is The Species Under Review Listed As A DPS?

___ Yes
_x_ No

2.1.3 Is There Relevant New Information For This Species Regarding The Application Of The DPS Policy?

Woundfin:
___ Yes
_x_ No

Virgin River Chub:
___ Yes
_x_ No

Note: This 5-year review and as proposed by the USFWS in the past (refer to section 1.3.3), a status review or candidate assessment of the Virgin River chub population that resides in the Muddy River in Nevada is warranted. In that review, the application of the DPS policy may be considered. The significant portion of range language of the ESA also may be considered.

2.2 RECOVERY CRITERIA

2.2.1 Does The Species Have A Final, Approved Recovery Plan Containing Objective, Measurable Criteria?

_x_ Yes
___ No

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?

_x_ Yes
___ No

Biological information presented in the 1995 Recovery Plan is not completely up to date; however, the guidance provided in terms of threat evaluation and reduction is still germane to recovery of the Virgin River Fishes. New information on the biology of the species and their habitat is discussed herein. The amount and nature of the new information does not warrant revision of the existing recovery criteria. If a status review of the Muddy River population of Virgin River chub results in listing, then the Recovery Plan may need to be revised.

2.2.2.2 Are All Of The 5 Listing Factors That Are Relevant To The Species Addressed In The Recovery Criteria?

_x_ Yes
___ No

The Recovery Plan correctly directs the USFWS, the participants of the Virgin River Resource Management and Recovery Program (Virgin River Program), as well as lower Virgin River recovery groups to focus on ameliorating the destruction and modification of habitat and to address the threat of disease and predation.

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 the Virgin River chub and then to secure each species' survival. Despite efforts of the Virgin River Program and the Lower Virgin River Recovery Implementation Team (refer to section 2.3.2.5 for a description of these and other entities involved in Virgin River fishes recovery), persistent threats exacerbated by prolonged drought have caused woundfin distribution to shrink and abundances to decline to the lowest recorded levels within the past 5 years. Therefore, the primary objective as stated in the Recovery Plan remains valid.

The Recovery Plan identifies specific down-listing and delisting criteria for the woundfin and the Virgin River chub. With the exception of one delisting criteria, which calls for the establishment of two new populations, these criteria are based on the reduction of threats. These criteria do not identify quantifiable thresholds, but it is the USFWS' opinion that the qualitative nature of these criteria is still appropriate based on the current level of threat. The Plan identifies 27 specific recovery actions and 17 sub-tasks under 5 major categories as a means to achieve recovery. Before we assess progress toward meeting the downlisting and delisting criteria we offer a cursory review of actions taken under each of these five recovery categories:

1) **Maintain and Enhance Native Fish Communities of the Virgin River Chub and Woundfin.** Specific actions called for in the Recovery Plan include: native fish monitoring; build barriers; and remove nonnative fish. The Recovery Team has monitored fish populations throughout the Virgin Rivers since 1976 and a database has been developed to store that information. The Virgin River Program has continued and expanded Recovery Team monitoring efforts in Utah since 2002 (Fridell and Morvilius 2005a). These data are referenced later in our assessment of population status. Two large scale nonnative fish barriers (Webb-Hill and Stateline) have been constructed on the Virgin River main stem in Utah, and one in the lower Muddy River of Nevada to assist in nonnative control. Several smaller scale barriers have been constructed on washes and irrigation returns. The Virgin River Program, coordinating with the State of Arizona and others, is poised to construct the next barrier in the Virgin River Gorge in Arizona. In addition, the Lower Virgin River Recovery Implementation Team is currently pursuing the design of a double-barrier system near the lower end of critical habitat at Halfway Wash in Nevada. The Recovery Team initiated red shiner treatments on the Virgin River in Utah, in 1988. These activities have been taken over by the Virgin River Program since 2001. Red shiner (*Cyrpinella lutrensis*) treatment activities to date have served to reduce the threat of expansion upstream of the Washington Fields Diversion, but have yet to eliminate red shiner in the target area (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.** Specific actions called for in the Recovery Plan include: monitor habitat and water quality; provide instream flows; develop legally binding agreements to protect flow; and acquire land and 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 had essentially been fully appropriated (USFWS 1995). A minimum flow of 3 cubic feet / second (cfs) has been secured below the Quail Creek Diversion through implementation of the Virgin River Spinedace Conservation Agreement (Lentsch et al. 1995). Return flows are protected downstream to the Washington Fields Diversion to meet the needs of irrigators and to provide

a biological benefit to Virgin River fish (USFWS 1982). The Virgin River Program is currently developing a flow recommendation for the Virgin River immediately downstream of Washington Fields Diversion. In the Santa Clara River, 3 cfs has been secured below Gunlock Reservoir via the Santa Clara pipeline project, which the Virgin River Program has 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: from Pah Tempe Springs to the Quail Creek Reservoir outflow at Stratton Pond in Utah; from the Washington Fields Diversion 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 Virgin River Program has collaborated with 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 Virgin River Program and other entities have pushed for local floodplain and erosion zone ordinances to indirectly achieve this objective.

3) **Establish Additional Populations of Woundfin and Virgin River Chub Within Their Historic Range.** Specific actions called for in the Recovery Plan include: maintain two refugia for woundfin and Virgin River chub brood stock; and identify reintroduction sites and protocols. A genetically diverse brood stock of woundfin is maintained at the Dexter National Fish Hatchery and Technology Center in Dexter, New Mexico (Dexter National Fish Hatchery and Technology Center 2006). 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 2.3.1.2). Woundfin from Dexter National Fish Hatchery and Technology Center have recently been transported to the State of Utah facility at Wahweap to establish a second captive population. Virgin River chub also are held at Dexter National Fish Hatchery and Technology Center and have been recently established at the Wahweap Hatchery. The Virgin River Program recently funded a study to characterize genetic diversity of the brood stock relative to the wild population.

In 1972, woundfin were transplanted into four locations in the Gila River system, but populations were not established. In 1985, the USFWS 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, the

USFWS recommended that the 10(j) ruling be withdrawn, due to the precarious status of the woundfin. We determined that all future reintroductions should receive full protection of the ESA. During the summer of 2007, the State of Arizona Game and Fish Department stocked hatchery reared woundfin in the Gila River drainage under the existing 10(j) ruling. As a result, the USFWS is not planning to withdraw the rule. We will continue to monitor this population and its contribution to recovery.

4) **Determine Ecological Requirements of Native Virgin River Fishes With Emphasis on Woundfin and Virgin River Chub.** Specific actions called for in the Recovery Plan include: describe historical variation in natural population abundance; determine relationships between environmental variables biology / life history; describe native fish community structure and interactions; and prevent loss of fish in irrigation canals. Monitoring has always considered the entire fish community. Due to the breadth of the data set (1976-present), strong correlations between environmental variables and relative abundance have been developed (refer to section 2.3.1.2).

   Habitat degradation within the Virgin River system fall into three general categories including: (1) physical (flow depletions and elevated water temperature; manipulation of the channel and encroachment on the floodplain; 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); and (3) biological (introductions of nonnative species and parasites). In 2004, the Virgin River Program and the Washington County Water Conservancy District coordinated releases from Kolob Reservoir to reduce stressful physical conditions in the Virgin River below Pah Tempe Springs. In addition, the Virgin River Program and the Lower Virgin River Recovery Implementation Team have directed significant effort to describe the nature and extent of limiting factors and have developed strategies to reduce them (e.g., effects of reduced flow and elevated temperature). The Washington County Water Conservancy District has developed and implemented an Interim Sediment Management Plan for their Quail Creek Diversion to protect the environment during future sluicing events. The Virgin River Program constructed a fish screen on the Washington Field Canal to reduce entrainment of endangered and other native fish, and has coordinated with the Washington County Water Conservancy District to provide a minimum flow below the Washington Fields Diversion while a flow recommendation is developed (refer to section 2.3.1.6 for more in depth review of these activities).

5) **Develop and Implement Educational and Informational Programs Highlighting Recovery Needs and Ongoing Efforts for Virgin River Fishes.** The Virgin River Program has recently contracted with a media consultant to handle this important aspect of recovery. Additional ongoing

educational and informational activities include: periodic school presentations with field trips, the Utah State University fish viewer, water fair presentations, coordinated media press releases and news reporting, and the recently established Virgin River program website (http://www.virginriverprogram.org/).

Downlisting Criteria Progress

Downlist Criterion #1: Virgin River flows essential to the survival of all life stages of the species 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 Pah Tempe 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.

Progress: This criterion addresses three of the five listing factors / threats (Present or threatened destruction, modification or curtailment of its habitat or range; Other natural or manmade factors affecting its continued existence; and Inadequacy of existing regulatory mechanisms). Progress has been made on securing flow in some reaches, but habitat conditions remain sub-standard in large reaches of the river, particularly during low water years. The Virgin River Program and Lower Virgin River Recovery Implementation Team have focused on the summer period as perhaps the most stressful and are working on ways to improve conditions (e.g., releases of cool water, experimentation with induced turbidity). While available data support the hypothesis that physical conditions during summer are the critical period for the Virgin River fish, efforts to resolve these limiting conditions have not provided enough relief to restore populations to some semblance of pre-development abundance.

Downlisting Criterion #2: Degraded Virgin River habitats from Pah Tempe Springs to Lake Mead are improved and maintained to allow continued existence of all life stages at viable population levels.

Progress: The second criterion addresses the same three threats. The Virgin River Program has expended significant resources to restore degraded habitat and to preserve healthy riparian areas. It remains uncertain whether enough habitat can be restored to recover these species in the face of long standing water use. Critical to meeting this criterion, and to achieving recovery of the Virgin River fish, will be implementation of the proposed Virgin River Habitat Conservation and Recovery Program (VRHCRP) (refer to section 2.3.2.5 for a description) in the Nevada portion of the Virgin River. Efforts to include the Arizona portion of the river in this program are ongoing. A

consistently funded partnership, similar to the Virgin River Program in the upper river, will be key to finding flexibility in current resource management practices and to affect meaningful and long term habitat restoration.

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

Progress: Since the mid-1980s red shiner (*Cyprinella lutrensis*) populations have increased substantially in the lower river; expanded their range upstream; and have created a persistent threat of expansion upstream of the Washington Fields Diversion. In 2002, red shiners were found upstream of Washington Fields Diversion, and Utah Department of Wildlife Resources (UDWR) demonstrated that a determined mechanical removal effort could be successful (Fridell et al. 2003). The Recovery Team, the Virgin River Program, and the Lower Virgin River Recovery Implementation Team have devoted considerable effort to controlling red shiner populations in the Virgin River system. To date, this effort has resulted in maintaining the status quo; a significant accomplishment itself. The Virgin River Program and the Lower Virgin River Recovery Implementation Team are currently pursuing construction of additional barriers to assist in future treatment. The results of long term monitoring (refer to section 2.3.1.2) demonstrate woundfin will not persist in the presence of red shiner. Woundfin recovery will be contingent on red shiner eradication. As was mentioned above, but of even greater significance when considering these down-listing criteria, will be the establishment of the VRHCRP and full cooperation of Arizona stakeholders. Red shiner removal must be confronted from a "whole river" perspective. This criterion is soundly based on the best available science, and despite significant effort has not been achieved.

Delisting Criteria

Delisting Criterion #1: Two additional self-sustaining populations are established in the wild within its historical range. This will require that adequate protection of available habitat and instream flows are maintained, the populations have been 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.

Delisting Criterion #2: Essential habitats, important migration routes, required stream flow, and water quality of both the Virgin River habitat and the habitat of transplanted populations are legally protected, and the threats of other significant physical, chemical, or biological modification such that the

habitat would become unsuitable for the woundfin are removed.
The Recovery Plan (USFWS 1995) determined that these delisting criteria for the woundfin were considered interim because the opportunity and the potential locations for re-establishment of additional populations were uncertain. At that time, the USFWS determined that delisting criteria for Virgin River chub could not be determined. As new information regarding Virgin River chub life history and population status becomes available, the USFWS should develop specific delisting criteria. Given the species current status, the ongoing focus on threat reduction is appropriate.

2.3 UPDATED INFORMATION AND CURRENT SPECIES STATUS

2.3.1 Biology And Habitat

2.3.1.1 New Information On The Species' Biology And Life History

Woundfin: As stated in the Recovery Plan (USFWS 1995), Hickman (1987b) compiled an annotated bibliography for the woundfin and summarized most available published papers and government reports on this species. Principal taxonomic works are contained in Cope (1874), La Rivers (1962), Miller and Hubbs (1960), Uyeno and Miller (1973), and Dexter National Fish Hatchery and Technology Center (2006). Distribution and status of woundfin are contained in Cross (1975, 1978, 1985), Deacon (1988), Hickman (1985, 1986, 1987a, 1988), Hardy et al. (1989), Holden et al. (2001), Holden et al. 2005, and Albrecht et al. (2007). Life history, reproductive biology, and ecology can be found in Deacon (1977a,1977b), Deacon and Hardy (1980, 1984), Deacon et al. (1987), Greger and Deacon (1982, 1986), and Heckman et al. (1986, 1987).

Woundfin adults and juveniles are most often collected from runs and quiet waters adjacent to riffles. Juveniles use habitats which are generally slower and deeper than those characteristic of the adults. Woundfin larvae are collected in backwaters or slow velocity habitat along stream margins, often associated with dense growths of filamentous algae.

Monitoring and research efforts have since expanded our knowledge of the species biology and life history. It appears that woundfin generation time is predominately limited to 1 year. Furthermore, woundfin must achieve sufficient growth (> 66 mm total length) prior to the spring spawning period in order to contribute to the next generation (Fridell and Morvilius 2005b). Critical and behavioral thermal maximum criteria are now better understood (see section 2.3.2.1), particularly how exceedence of these thresholds continue to threaten woundfin in the upper and lower Virgin River.

Virgin River Chub: Very little information exists on the life history and ecology of the Virgin River chub. Most literature deals primarily with the taxonomy and distribution of the species. Discussions on the taxonomy include Cope and Yarrow (1875), Ellis (1914), Snyder (1915), Tanner (1936), Miller (1946), LaRivers and Trelease (1952), Holden and Stalnaker (1970), Minckley (1973), and DeMarias et al. (1992). Information on the distribution is documented in Miller (1946), Holden and Stalnaker (1970), Minckley (1973), Cross (1975), Hickman (1985, 1986, 1987a, 1988), Hardy et al. (1989), Holden et al. (2001), Golden and Holden (2005, Holden et al. (2005), and Albrecht et al. (2007). Life history and habitat requirements are discussed in La Rivers (1962), Minckley (1973), Deacon and Minckley (1973), Cross (1978), Schumann (1978), Hickman (1987a), and Hardy et al. (1989). Hickman (1987c) compiled an annotated bibliography for the Virgin River chub which contains most of the known publications and government reports dealing with the species.

Long-term monitoring in the upper river, where red shiner do not occur, indicate that the longer lived Virgin River chub appear to reproduce successfully in most years. In addition, some level of recruitment to the adult population appears to occur on a frequent basis (based on the consistent collection of Age-1+ and Age-2+ chub) (Fridell and Morvilius 2005a, Golden and Holden 2005, Albrecht et al. 2007).

A review of historical data indicated that two "core populations" of Virgin River chub (one in the upper river and one in the lower river) appear to be more tolerant of habitat conditions that limit the woundfin. Alternatively, the fact that Virgin River chub are longer-lived may allow for periodic recruitment, while populations of the shorter-lived woundfin are impacted by one poor recruitment year. A comparison of recent data collected at these two core populations indicates that, like woundfin, Virgin River chub are negatively affected by the presence of red shiner and other nonnative fish. However, unlike woundfin, Virgin River chub are able to persist where they are sympatric. A recent effort to estimate Virgin River chub population size at small sites within these two core areas provided a valuable piece of baseline data, which indicates abundance in the upper river core area, where red shiner are absent, may be nearly 10 times greater than in the lower river core area.

2.3.1.2 Abundance, Population Trends, Demographic Features, Or Demographic Trends

Historical distributions of woundfin and Virgin River chub were described in the Recovery Plan. Since 1976, specific locations on the Virgin River in Utah, Arizona, and Nevada have been sampled annually by the Recovery Team. The Recovery Team stations are distributed throughout

critical habitat starting upstream near the Ash Creek confluence (Utah; sampling centered around rive mile 95); Hurricane Bridge, (rive mile 86); Twin Bridges, (rive mile 71.5); Atkinville Wash, (rive mile 55); Beaver Dam Wash, Arizona (rive mile 35); Mesquite, Nevada (rive mile 21); and Riverside, Nevada (rive mile 12). Monitoring, which consists of sampling with small-meshed seines, was conducted during all seasons in some years and some locations, but was most consistently conducted in the spring, typically during April or May, and again in the fall, typically during September or October. Seining, designed to target woundfin and other small sized fish, proved to be reliable technique to collect early life stages of Virgin River chub, but other techniques (e.g., hoop nets) work better for late juvenile and adults (Golden and Holden 2005). Early monitoring efforts by the UDWR relied upon a two-pass electrofishing strategy and concentrated the sampling to the fall only. Current population monitoring is conducted on the main stem at target flows less than ~ 300 cfs based on sampling efficiencies restricted by higher water.

Monitoring data, along with information from various other research and monitoring efforts, have been combined into a centralized database maintained at Utah State University, Logan, Utah. Over the years various resource managers have accessed these monitoring data for a variety of investigations: a) to describe population dynamics as function of flow (Deacon and Hardy 1984, Hardy et al. 1989, Gregory and Deacon 1994, Hardy et al. 1995); b) to describe variability in the data set itself (Hardy et al. 1989); c) to describe population status (Hardy 1991); and d) to evaluate proposed management strategies (Hardy 1994).

The long-term monitoring program, particularly in the early years was a volunteer effort conducted by Recovery Team representatives. Long-term monitoring was not designed to generate population estimates and, therefore, any analysis that considers catch indices also must consider inherent variability (environmental and human induced). To address these uncertainties, Holden et al. (2001) carefully reviewed the Virgin River database and gleaned a more standardized data subset, which reduced variability. They settled on number of woundfin per “seine unit” as their standardized catch metric, which also had been selected by previous researchers to describe long-term trends (Deacon 1988). This metric expresses fish density as the mean number of fish per seine unit in fall samples, and a “seine unit” was defined as the multiple seine hauls at one location during one sampling. The number of seine hauls varied from 3 to 10 or occasionally more.

In recent years and under the auspices of the Virgin River Program, UDWR has greatly expanded the scope and intensity of fish community monitoring in Utah (upper river). Similarly, in the lower river (Virgin River in Arizona and Nevada) a variety of interested agencies, or their

contracted private consultants, has increased sampling efforts to bolster the Recovery Team monitoring and to answer specific research / management questions. Results of these more rigorous sampling efforts have been used to test the validity of established, but less intensive Recovery Team monitoring data to track population trends. It is the general consensus of species experts that the Recovery Team data is a useful tool in tracking large scale shifts in the endangered fish populations (Richard Fridell, UDWR-St George, Utah, pers. comm., January 24, 2007) and, therefore, is appropriate for this type of review.

From a population status perspective, the most comprehensive analysis of the Recovery Team monitoring data occurred 6 years ago when Holden et al. (2001) reviewed 24-years (1976 – 1999) of information to evaluate changes in the woundfin populations at four stations: Ash Creek, Hurricane Bridge, Twin Bridges, and Beaver Dam Wash (Figure 1). Those locations were selected because they were the most commonly sampled since the 1970s, and because they represent unique areas in terms of habitat and environmental stressors. Since the Holden et al. 2001 review, several efforts have been made to update that analysis in the lower river, Arizona and Nevada (Golden and Holden 2004 and Albrecht et al. 2007), and in the Upper River (Utah stations, Fridell and Morvilius 2005a). These are the primary sources of information used to describe trends in abundance and distribution at these four main stem areas. Depending on the specific station, resource managers correlated a suite of flow metrics with population density to describe observed changes. Other contributing factors, albeit more qualitative, include: effects of Quail Creek Dam failure in 1989; negative interactions with nonnative species (particularly red shiner); effects of periodic red shiner removal efforts (mechanical and chemical); and periodic release of hatchery-reared woundfin. What follows is a summary of the population status information collected from 1976 to 2006 at four Recovery Team monitoring sites.

The reader should note that based on preliminary sampling results collected in 2007 resource managers have determined that the wild woundfin population was functionally extirpated throughout critical habitat. Causes for this most recent decline in woundfin numbers was attributed to the following suite of environmental conditions: continued drought with summer temperatures exceeding behavioral thermal maximum and critical thermal maximum; runoff from burned portions of the drainage; and the input of sediment from behind the Quail Creek Diversion Dam. Hatchery raised woundfin were stocked in the upper Virgin River in the Fall 2007; additional releases are planned in the future.

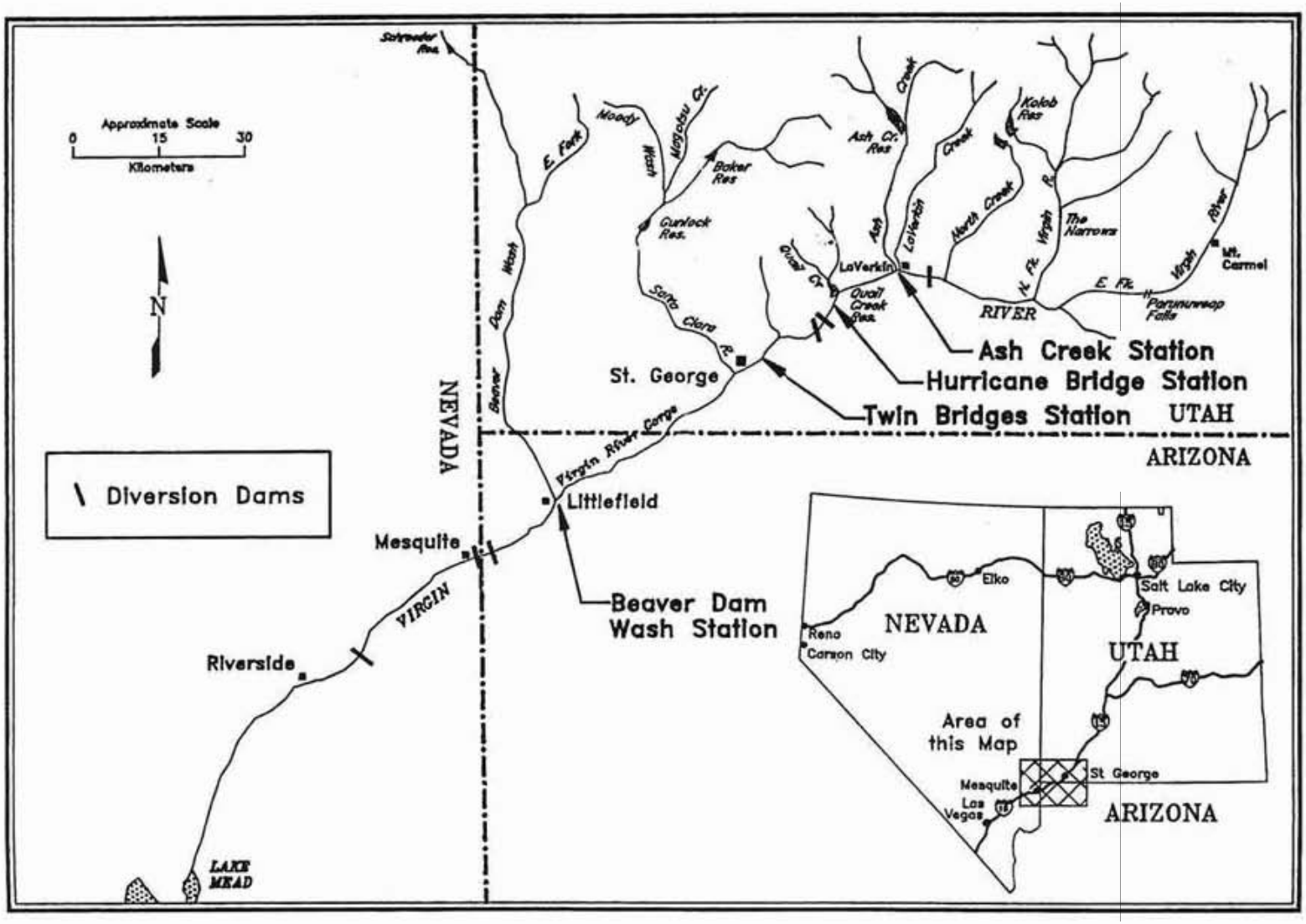

Figure 1. The Virgin River Drainage, Utah, Arizona, Nevada with four long term Recovery Team sampling stations delineated.

Ash Creek: Sampling has been conducted a short distance downstream of the Pah Tempe Springs, which release warm, highly saline waters into the Virgin River main stem. Prior to human development, this saline water was immediately diluted by much larger Virgin River base flows. Virgin River hydrology at the Ash Creek station has been drastically affected by a long history of diversions a short distance upstream (refer to section 2.3.2.1). Fish populations at the Ash Creek station benefit from tributary flow from, and habitat provided in lower Ash and LaVerkin Creeks.

Holden et al. 2001 reported autumn (August 15 – November 15) woundfin abundances ranged from 0.75 to in excess of 4.0 woundfin per seine unit (actual values refer to *ln* (woundfin per seine unit +1)) from 1976 through the mid- 1980s, which was only slightly less than abundances recorded at sites downstream (Figure 2). They reported a sharp drop in the woundfin abundance from 1985 to 1986, which Hardy et al.(1995) attributed to the formation of sinkholes increasing the amount of saline releases from Pah Tempe Hot Springs, thereby negatively impacting water quality. Gregory and Deacon (1994) further associated the mid-1980s decline in woundfin abundance at Ash Creek station to operations at Quail Creek Diversion, which reduced the capacity of the Virgin River to dilute the increased output from Pah Tempe Hot Springs.

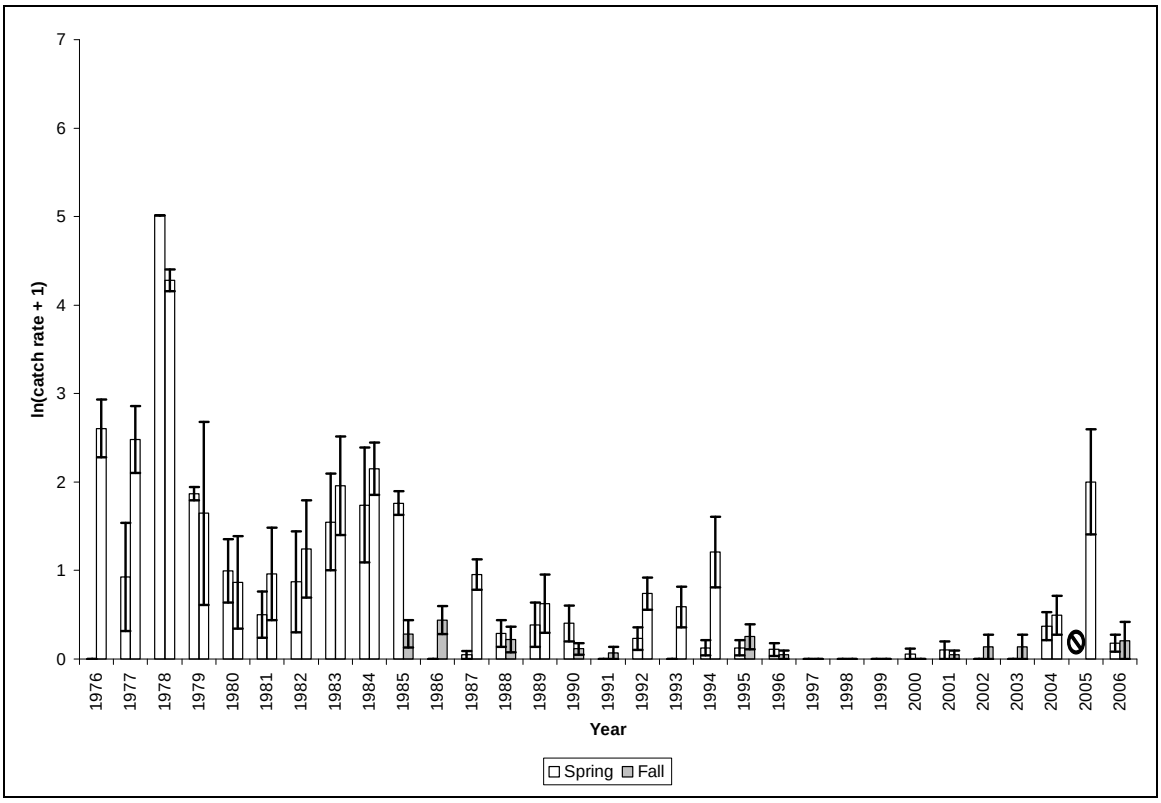

Figure 2. Woundfin catch rate near the Ash Creek Recovery Team Station in spring and fall sampling between 1976-2006. Error bars = +/- 1 standard error.

Since the mid-1980s, there have been brief periods of rebound; however,

woundfin numbers at the Ash Creek station have remained generally low. Periods of drier hydrology appear to coincide with the lowest catch rates for woundfin at this station. For the first time since 1976, no woundfin were captured at this station in 1996. They remained absent from collections through the fall of 2000, and precariously low through the early 2000s. A variety of resource managers have focused on high summer temperatures (a byproduct of extreme low flow) as perhaps the key factor limiting survival of woundfin in this portion of the river (Deacon et al. 1987, Addley 2006, Rehm et al. 2006).

In response to the drastically low numbers of woundfin in this portion of the river from the late 1990s through the early 2000s, the Virgin River Program stocked hatchery-produced woundfin in the Virgin River Ash Creek for the first time in 2003. Additional releases have occurred each year since 2003. All hatchery fish were marked prior to release with injectable elastiomers. Initial results indicate that dispersal and survival have been low. However, UDWR has learned that survival of stocked fish > 65 mm total length is better than smaller individuals (Fridell and Morvilius 2005b). Researchers at the Dexter National Fish Hatchery and Technology Center have detected some genetic contribution from the hatchery stock to the wild population (Dexter National Fish Hatchery and Technology Center 2006).

In 2004, a combination of Virgin River Program activities and environmental circumstances provided the first indications of a positive population response in the upper Virgin River in 9 or 10 years (Fridell and Morvilius 2005a). More specifically, the Washington County Water Conservancy District coordinated with the Virgin River Program to release cool water from Kolob Reservoir during a period of stressful summer river temperatures; summer weather cooled during the same stressful time period to somewhat ameliorate the baseline level of stress in the river; and the Virgin River Program had augmented the wild population with hatchery produced fish. Fall 2004 woundfin catch rate at the Ash Creek Recovery Team station rose from near zero to 0.5 woundfin per seine unit. The following year, Virgin River hydrology turned wet with daily peak flows (recorded at the U.S. Geological Survey Virgin River Near Virgin, Utah: station: 09406000) in excess of 4,000 cfs on October 21, 2004 and January 11, 2005 and spring flows in excess of 200 cfs through July 1, 2005. Spring sampling was compromised by high flows, but resource managers were able to determine that woundfin successfully spawned. Sampling later that year clearly indicated an extremely successful reproductive event had occurred. Fall 2005 woundfin catch rate jumped to nearly 2.0 woundfin per seine unit, the highest catch rate recorded since 1984. However, woundfin spawned late in 2005 and many were too small to reproduce the following year. The UDWR resource managers are closely monitoring the population in the

upper river to determine the out-year effect of the population response detected in 2005.

A review of more intensive monitoring data indicates that only a small percentage of hatchery fish stocked in 2003 and 2004 were likely large enough to spawn in 2005 (Fridell and Morvilius 2005b). However, a recent genetic study determined that the captive stock did contribute to recruitment in the wild (Dexter National Fish Hatchery and Technology Center 2006).

Virgin River chub have been collected at the Ash Creek station (Figure 3) consistently throughout the 30-year Recovery Team monitoring effort and in high abundance relative to other areas of occupied habitat (Virgin River Database). Recovery Team monitoring (seining) primarily targets young of the year and juvenile chubs and, therefore, measures annual reproductive success.

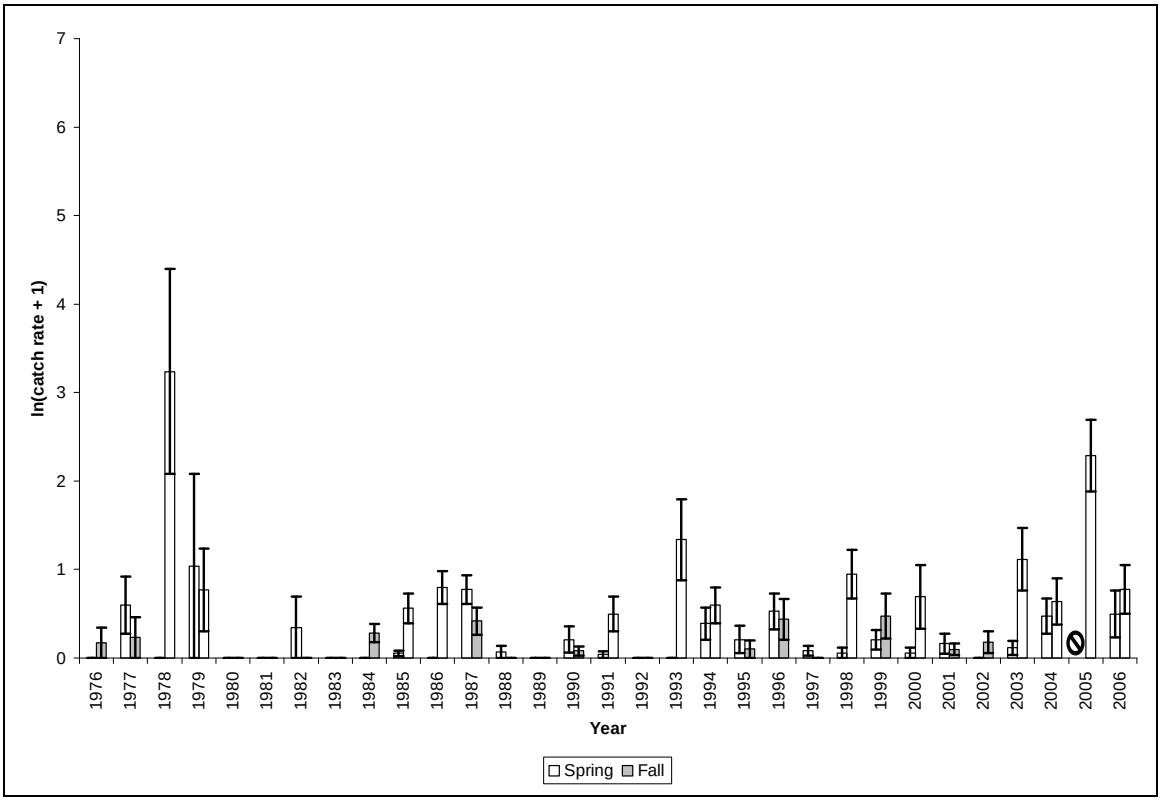

Figure 3. Virgin River chub catch rate near the Ash Creek Recovery Team station in spring and fall sampling between 1976-2006. Error bars = +/- 1 standard error.

The highest Fall abundance of chub at the Ash Creek site was recorded in 1978. The second highest was recorded in 2005. Recovery Team data indicate that Virgin River chub populations in this portion of the Virgin River persisted when woundfin did not. Similar to woundfin, Virgin River chub benefited from the high flows in this portion of the river in 2005.

Previous research (Fridell et al. 2004, Morvilius and Fridell 2004, Schijf et al. 2004, and Golden and Holden 2002) has demonstrated that the Upper Virgin River (rive mile 97.5 – 90.0) supports one of two "core areas" for Virgin River chub in the Virgin River system. Core area designation references historical data and describes locations where Virgin River chub have been collected consistently and in relatively high numbers. Another core area is located in the lower portion of the Virgin River Gorge near Beaver Dam Wash (rive mile 39.5-34.0). In 2004, the Virgin River Program, recognizing that Recovery Team monitoring protocols were not tracking abundances of adult chub and other large-bodied Virgin River fish, convened a committee to consider development of a Virgin River chub Monitoring Plan. That committee recommended: a) determine the existing distribution, population size, and size structure of Virgin River chub throughout the Virgin River system, and b) develop a sampling methodology to track the status and trends in Virgin River chub population size and size structure on an annual basis. To meet the first objective resource managers used a variety of techniques to conduct a multiple pass, mark / recapture population estimate in a 0.5-mile section in each of the core areas. The population estimate for the upper core area was 3,209 (95% confidence interval: 2,496-4,204) Virgin River chub larger than 150 mm and 4,996 (95% confidence interval: 4,221 – 5,971) Virgin River chub smaller than 150 mm (Golden and Holden 2005). The estimated size of the Virgin River chub population in the upper core area was nearly 10 times as large as that estimated in the lower core area.

To summarize Ash Creek results since the Recovery Plan was revised in 1995, woundfin abundance has generally declined. Virgin River chub abundance is variable, but appears to have been more stable during the past 12 years. More recent data also indicate that this area supports the highest abundance of Virgin River chub throughout its critical habitat. The primary threats to the Virgin River fish in this portion of the river are largely due to long standing water development projects that continue to cause significant flow reductions. In recent years, releases of cool water during stressful summer months, population augmentation, and other recovery actions (refer to section 2.3.2.1) were implemented to reduce threats. However, the effects of severe and persistent drought through much of this timeframe have overshadowed those efforts and resulted in a net loss of habitat quality. The remaining wild population of woundfin, although depleted in this uppermost reach of occupied habitat, was capable of a strong reproductive response to wetter hydrology in 2005.

Hurricane Bridge: The Hurricane Bridge station is situated in the least impacted reach of the Virgin River. Other than suffering the brunt of the Quail Lake dike breach in 1989, the only clear disturbances at this station have been drought and changes in flow and water quality resulting from the construction of Quail Creek Reservoir. This station is situated

immediately downstream of the point of return flow from Quail Creek Reservoir. Flows through this portion of the Virgin River are maintained at 86 cfs (or the unregulated flow of the Virgin River if less) to satisfy water rights at the Washington Fields Diversion and to assist in the recovery of the Virgin River fish as required by the USFWS Biological Opinion for Quail Creek Dam and Reservoir (USFWS 1982). Summer releases from Quail Creek Reservoir are cooler and less turbid than pre-project conditions. This station is located upstream of the Washington Fields Diversion and, therefore, has had little to no impact from red shiner or chemical treatment efforts.

In their analysis of 25 years of Recovery Team monitoring data, Holden et al. (2001) determined that Hurricane Bridge had the highest and most consistent numbers of woundfin, river-wide. The 7 most recent years of Recovery Team sampling corroborates that finding (Figure 4). From 1977 through 1988, autumn abundance ranged from greater than 1.0 to over 3.0 woundfin per seine unit. Abundance dropped in 1989 after the dike breach (66,000 cfs at the Hurricane gage) and fell lower in 1990, which was attributed to drought conditions. The population rebounded in the Fall 1991 and remained moderately high through the fall of 1996 when the next period of low flow occurred. Holden et al. (2001) also report that woundfin abundance at the Hurricane Bridge site was most directly correlated with periods of recent drought. The amount of spring runoff explained over 40% of the variation in fall woundfin abundance at this station. However, woundfin abundance failed to rebound when flows increased in 1998 and 1999, which caused Holden et al. (2001) to speculate that repopulation from upstream sections may be a factor in woundfin population dynamics. Therefore, the crash of the Ash Creek population may have influenced the ability of Hurricane Bridge to rebound after perturbation.

More recent Recovery Team monitoring indicates that woundfin abundance at the Hurricane Bridge station rebounded slightly in 2000 (not detected upstream at the Ash Creek station), but then dropped and remained precariously low through Fall 2004. In 2005, similar to sampling results from the Ash Creek station, the diminished woundfin population at Hurricane Bridge demonstrated a strong positive reproductive response to high flows. Fall woundfin abundance in 2005 at Hurricane Bridge, was the highest recorded in 10 years.

The UDWR's recent analysis of 30 years of Recovery Team monitoring at Hurricane Bridge indicates abundances of Virgin River chub have been generally lower than those recorded upstream at Ash Creek, but have remained consistent. Additionally, recent hoop net sampling near the Hurricane Bridge station indicates significantly lower numbers of juvenile and adult Virgin River chub than near the Ash Creek station (Michael Golden, UDWR, pers. comm., February 22, 2007).

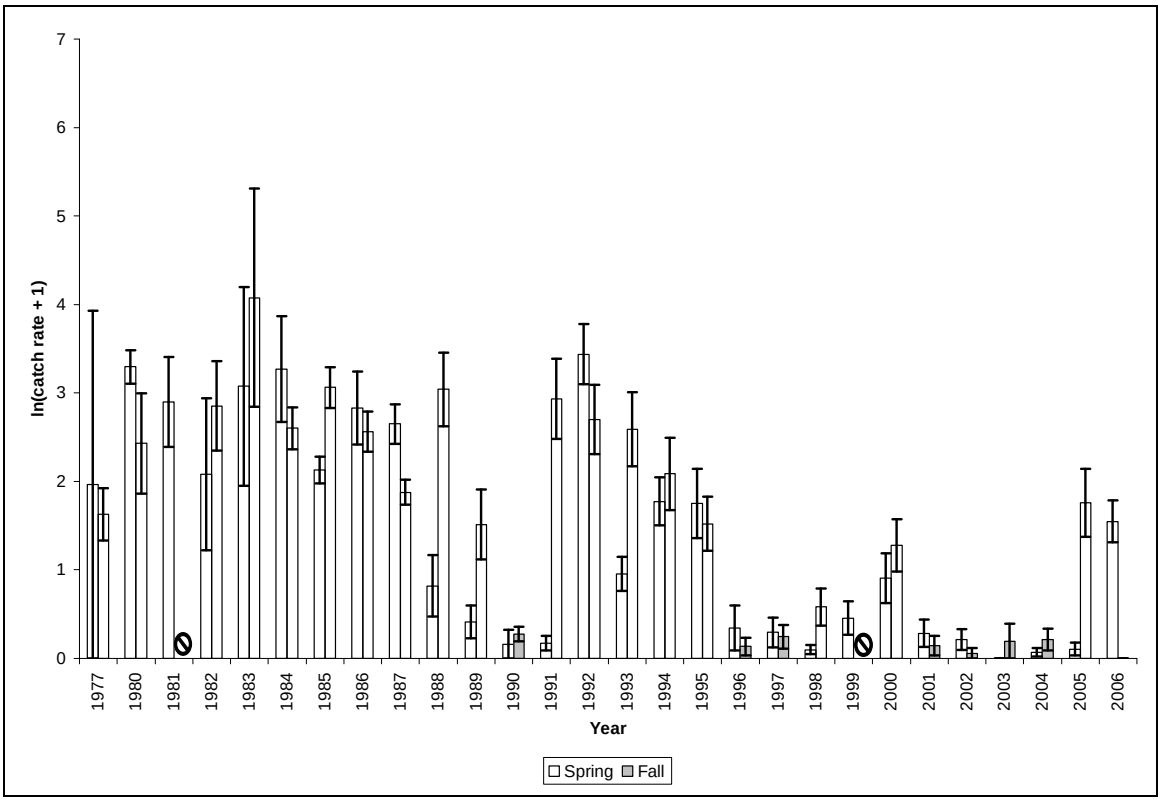

Figure 4. Woundfin catch rate near the Hurricane Bridge Recovery Team station in spring and fall sampling between 1976-2006. Error bars = +/- 1 standard error.

Since the Recovery Plan revision in 1995, woundfin abundance at the Hurricane Bridge station has faired better than all other locations, but it too has declined. The abundance of juvenile Virgin River chub is less well understood, but appears to be more stable than woundfin (Figure 5). There are fewer threats to the Virgin River fish in this portion of the river than elsewhere because red shiner have never become established and habitat is protected with a minimum flow requirement. However, this reach of river is bracketed by the threat of water depletions upstream (as described in the Ash Creek discussion) and downstream (due to the Washington Field Diversion). Until red shiner are pushed farther downriver and adequate flows are restored above the confluence with Quail Creek and below the Washington Fields Diversion, resource managers will rely heavily on this 6- to 7-mile reach of the river to sustain a wild population of woundfin.

Twin Bridges: The Twin Bridges Recovery Team station is the first subjected to the full suite of threats mentioned in the introduction to this section. Irrigation returns comprise the majority of Virgin River flow at this location during the baseflow period. This reach was subjected to the Quail Lake dike breach in 1989. Until recently, the river was periodically dewatered at the Washington Field Diversion (constructed in the early 1900s), which is

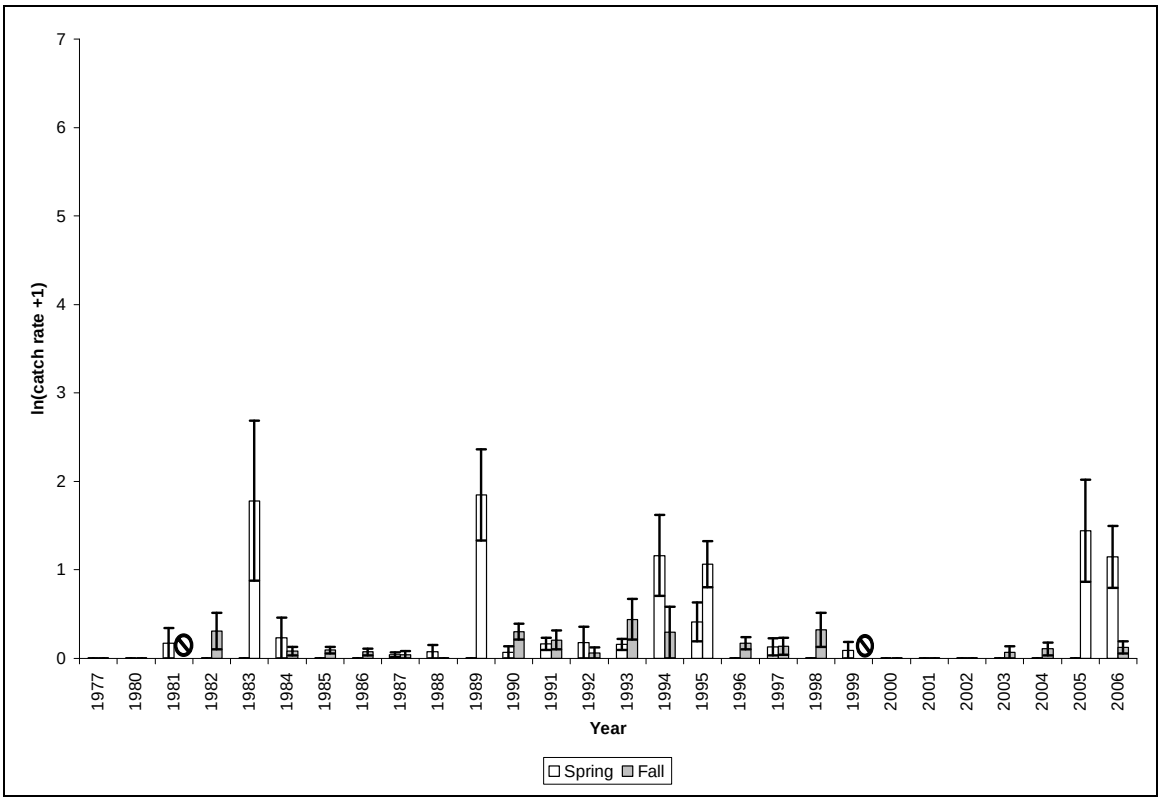

Figure 5. Virgin River chub catch rate near the Hurricane Bridge Recovery Team station in spring and fall sampling between 1976-2006. Error bars = +/- 1 standard error.

located 8 miles upstream of the Twin Bridges station. Native fish had been entrained into the Washington Fields Canal until the Virgin River Program constructed a fish screen in 2005. Red shiner became established in this reach of the river in the 1980s. On several occasions since 1988, native fish have been translocated above the Washington Fields Diversion in preparation for rotenone treatments. Rotenone treatments have been completed in this reach of river 13 times since 1988.

Holden et al. (2001) reported similar woundfin abundances at Twin Bridges and Hurricane Bridge through 1985, but then abundances at Twin Bridges declined significantly (Figure 6). The decline was linked to the establishment of red shiner; however, woundfin persisted in low numbers. Holden et al. (2001) found that woundfin abundance was significantly lower in drought years (1989-1991, 1994, and 1996-1997). The combined effects of drought, the Quail Creek Dike breaching in 1989, and rotenone treatments in 1988 and 1989 would explain the extremely low woundfin abundance from 1989-1991. From 1992-2006, woundfin abundances at Twin Bridges have remained extremely low (with the exception of fall 1995) and variable. Holden et al. (2001) linked years when woundfin were absent with low water years. Complicating this analysis in recent years was an increasing Virgin River Program effort to control red shiners, (i.e., rotenone treatments) (Comella and Fridell 1998, Fridell et al. 2004, Fridell et al. 2005).

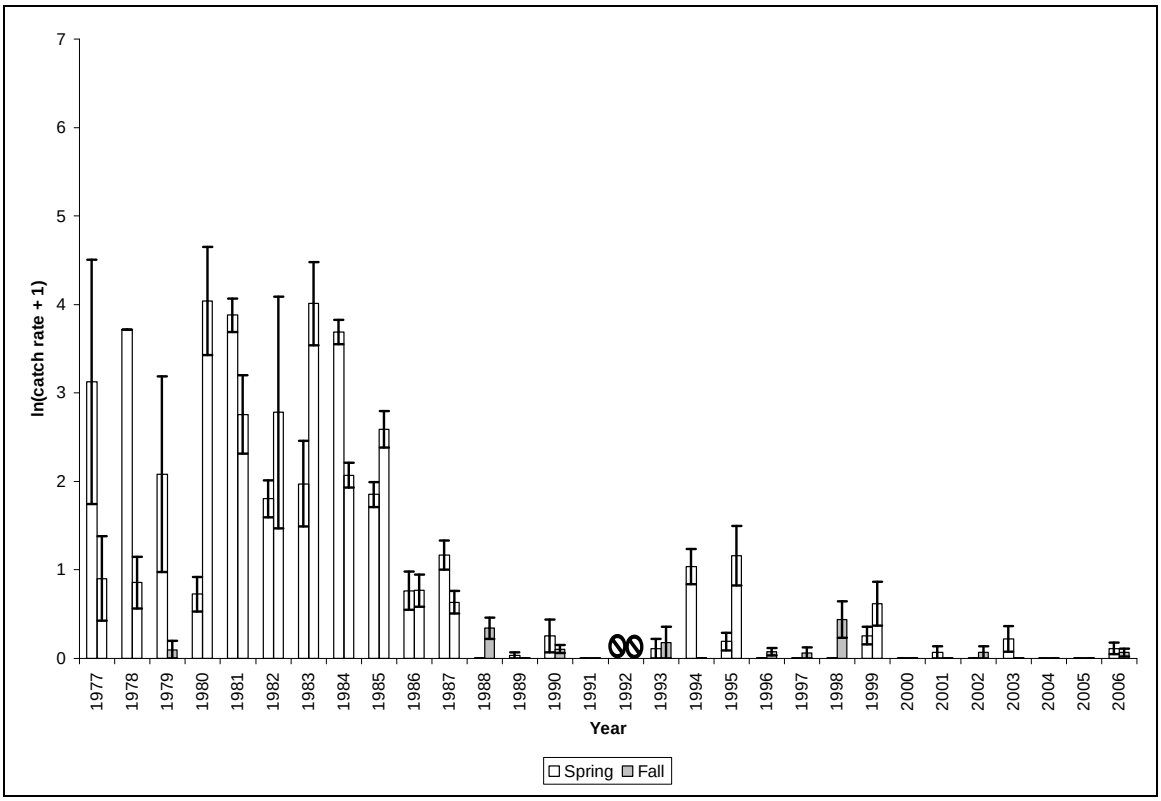

Figure 6. Woundfin catch rate at the Twin Bridges Recovery Team station in spring and fall sampling between 1976-2006. Error bars = +/- 1 standard error.

Holden et al. (2001) considered the effect of downstream drift on woundfin abundance at Twin Bridges. They found a significant positive relationship between mean woundfin abundance at Twin Bridges and mean woundfin abundance at Hurricane Bridge. In low flow years, dry stretches of channel appear between the two stations, which prevent woundfin from reaching the Twin Bridges station except during large scale events (e.g., thunderstorms). A combination of factors appear to be involved in the continued low numbers of woundfin at Twin Bridges, although the crucial period of decline is linked with the appearance of red shiner.

Virgin River chub have never been abundant at the Twin Bridges station, and have been absent in 9 of 30 years of Recovery Team sampling at this site (Figure 7). The paucity of chubs reported in this reach of river is likely a function of the lack of preferred habitat. The Twin Bridges station is characterized by relatively broad floodplain and shallow channel gradient. Virgin River chub prefer deeper pools and fast runs which are found more often in association with higher gradient sections and larger substrates.

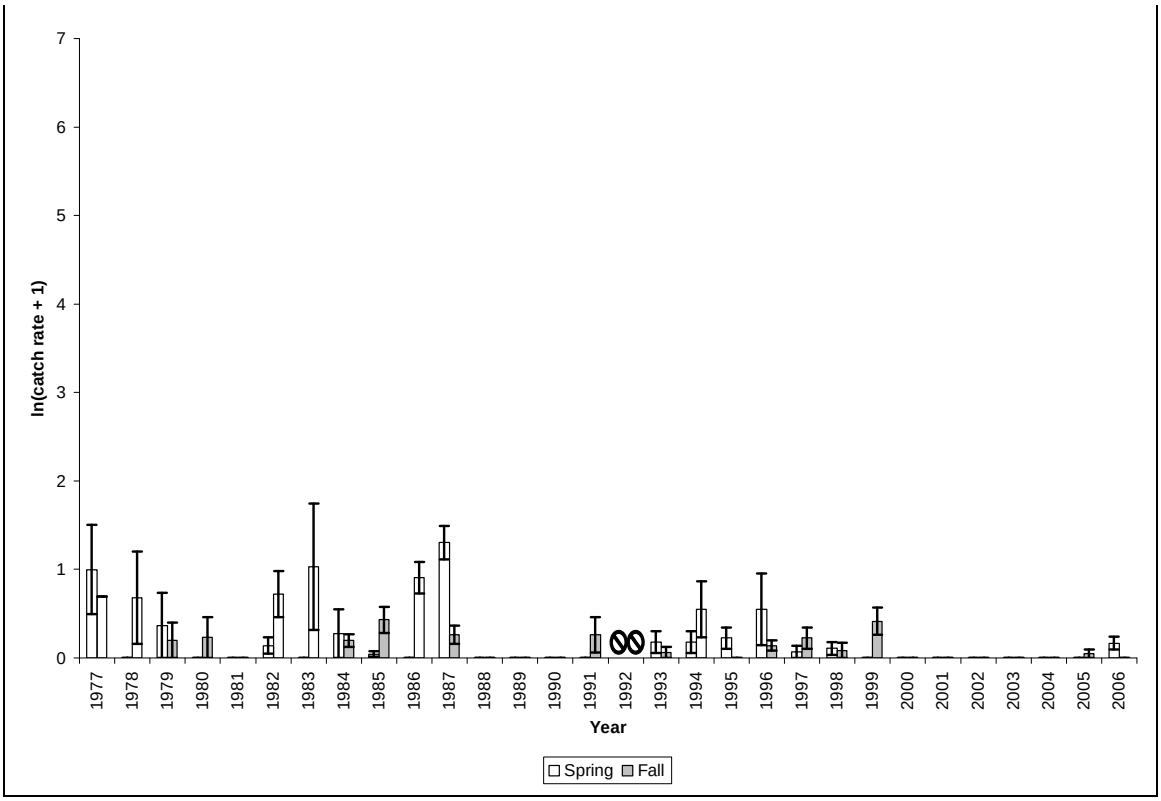

Figure 7. Virgin River chub catch rate at the Twin Bridges Recovery Team station in spring and fall sampling between 1976-2006. Error bars = +/- 1 standard error.

In summary, since the Recovery Plan was revised in 1995, the abundance of Virgin River fish (both woundfin and Virgin River chub) near Twin Bridges has remained unchanged; low in wet years and periodically lost altogether. Whereas, this reach of river is subject to the full suite of threats known to Virgin River fish recovery, recent construction of a fish screen at the Washington Fields Diversion and the concomitant effort to restore an adequate base flow at that point in the river will reduce the threats associated with historical water development. Located downstream of the Washington Fields Diversion, Virgin River fish populations at Twin Bridges are positioned to demonstrate the quickest response to successful red shiner removal efforts and flow restoration in the future.

Beaver Dam Wash and other Lower Virgin River Stations: Beginning in the lower Virgin River Gorge, 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). Fish populations at Beaver Dam Wash have been impacted with the same suite of stressors as mentioned for the Twin Bridges station

with a few exceptions. Although the Beaver Dam Wash station was inadvertently affected by the first rotenone treatment in 1988, none of the subsequent treatments that occurred in Utah affected this reach of river. Red shiner became established at the Beaver Dam Wash station in the early 1970s (Cross 1975), and began to flourish by 1986 and 1987 (Holden et al. 2001). 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 U.S. Geological Survey'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.

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 8). Whereas, Holden and Abate (1999) reported low numbers of woundfin in their Beaver Dam Wash sampling in 1996 and 1997, naturally produced woundfin have remained largely absent from collections through 2006 (Albrecht et al. 2007). Holden et al. (2001) found a fairly strong negative relationship when woundfin abundance was regressed against red shiner abundance at this station. Red shiner have likely been present in the lower river since the 1940s. The growth of a red shiner population at this station has long been linked to the extirpation of woundfin. Furthermore, Holden et al. 2001 speculated that the elimination of the lower river population of woundfin may be, in part, a function of declining populations upstream (i.e., lack of downstream drift from upstream areas).

Reduced flows have long been deemed one of 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). However, there also appears to be an upper threshold to the beneficial effects of flow. At the Beaver Dam Wash station flows peaked between 35,000 to 40,000 cfs in 2005. Sampling that year indicated the abundance of all species was reduced. By autumn 2005, native fish abundance remained low while red shiner abundance rebounded to pre-flood densities. Albrecht et al. (2007) maintained that low summer flows may be the most important factor limiting native fish populations at Beaver Dam Wash. The peak flows of 2005 appeared to negatively affect spring spawning native species. Unfortunately, red shiners, a species capable of spawning multiple times in a year, were able to quickly recover as flows dropped later that summer.

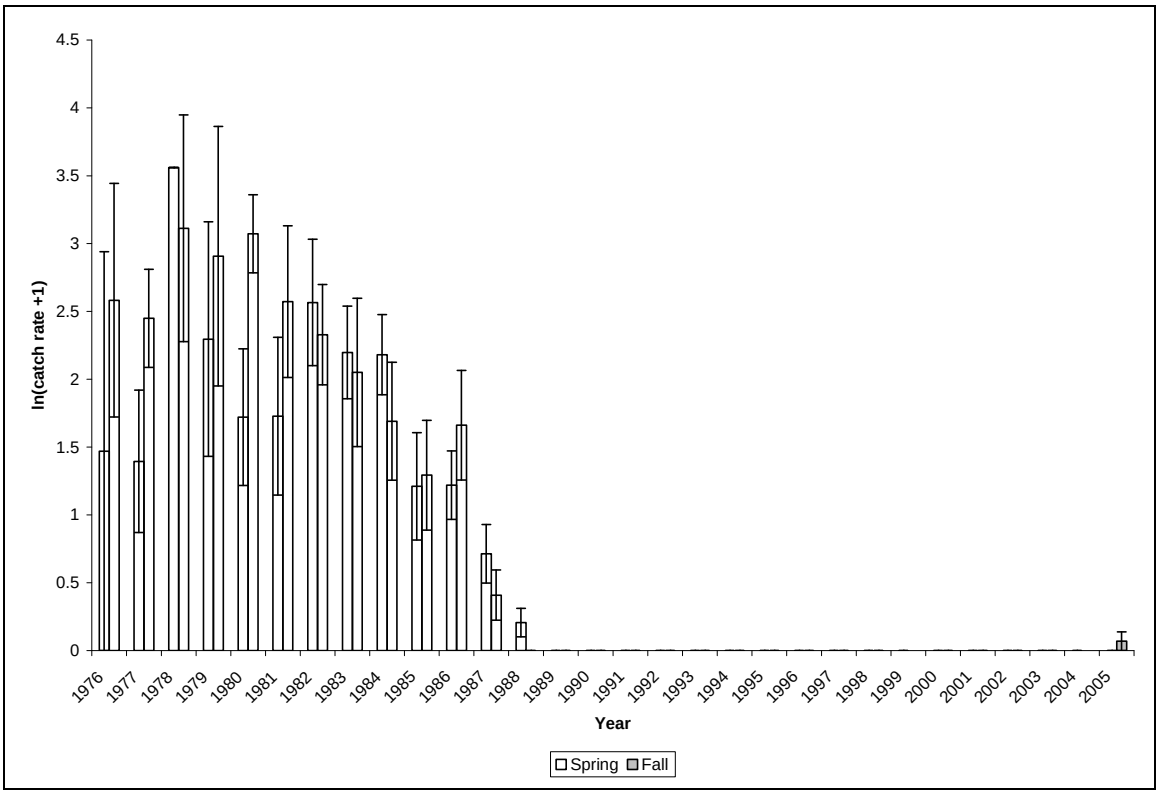

Figure 8. Woundfin catch rate at the Beave Dam WashRecovery Team station in spring and fall sampling between 1976-2005. Error bars = +/- 1 standard error.

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). Golden and Holden (2004) sampled these areas from 1996 – 2002. They reported dramatic declines of woundfin and other native species during the drought years of 1999 through 2002. No woundfin were collected by the fall of 2001 and none were collected in 2002, the lowest flow year on record. Albrecht et al. (2007) report that woundfin have remained absent in this lowest portion of the Virgin River since that time.

Woundfin stocking was started earlier in the lower river with multiple releases from 1993-1998. 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. Whereas, red shiner removal efforts were effective in the short-term when conducted under favorable environmental

conditions; 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 7-8 months, and reproduced successfully. Unfortunately, successful recruitment from the reproduced cohort was negligible, which was probably the result of similar summer critical limiting factors as have been discussed for the upper river. Resource managers did conclude 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. A total of 2,200 woundfin were stocked in this area in November, 2003; 800 and 250 were stocked in 2004 and 2005, respectively. Sampling 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.

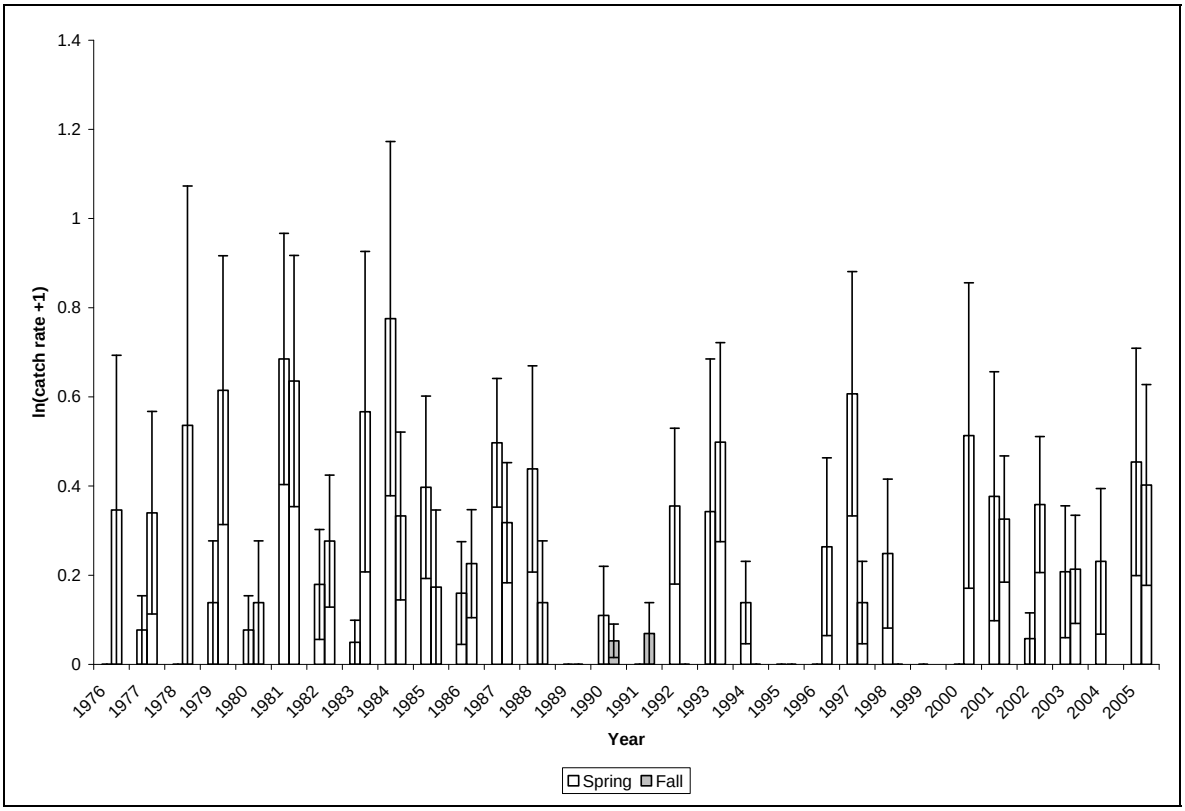

Figure 9. Virgin River chub catch rate at the Beaver Dam Wash Recovery Team station in spring and fall sampling between 1976-2005. Error bars = +/- 1 standard error.

The Virgin River in the vicinity of the Beaver Dam Wash station constitutes the second core area for Virgin River chub. Resource managers report collections of Virgin River chub 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 9). Golden and Holden (2004) reported a peak in Virgin River chub reproductive success in the spring 2002; however, fall abundances of young of the year had declined to more typical levels. More recently, 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 had declined to more normal levels (Albrecht et al. 2007). In 2004, a multiple pass, mark recapture population estimate was conducted throughout a 0.5-mile 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. Resource managers determined that the density of chub at Beaver Dam Wash was approximately 10% of that estimated at the core area near the Ash Creek Recovery Team station in Utah (Golden and Holden 2005).

The river near Beaver Dam Wash is characterized by a relatively high percentage of riffle and pool habitats. The Virgin River downstream of Beaver Dam Wash is comprised of more run-type habitats. 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); absent in most years.

In summary, since the Recovery Plan was revised in 1995, woundfin near Beaver Dam Wash remain absent. They were extirpated by 1990. Woundfin in downstream areas have been extirpated since 1995. The Virgin River chub population persists, but is much less abundant here than in the upper river. This reach of river is subject to the full suite of threats known to Virgin River fish recovery, and has not yet directly benefited from the establishment of a consistently funded partnership, similar to the Virgin River Program in the upper river. Agencies and entities in the lower river have long seen the need to establish a plan similar to the Virgin River Program, and are now poised to establish the VRHCRP for Nevada in part due to funding from the passage of the Mesquite Lands Act, and other land bills in Clark County. A coordinated recovery effort that includes both Arizona and Nevada portions of the river will be needed to complement efforts in the upper river.

2.3.1.3 Genetics, Genetic Variation, Or Trends In Genetic Variation

A study was recently conducted to determine the following: whether woundfin in the Virgin River were genetically similar to captive stocks at Dexter National Fish Hatchery and Technology Center; and whether stocked fish were contributing to wild recruitment (Dexter National Fish Hatchery and Technology Center 2006). The results of that study indicated that the captive and wild stocks had similar high levels of

genetic diversity as reflected by heterozygosity values and numbers of alleles. The resource managers concluded that woundfin residing in the river and at Dexter National Fish Hatchery and Technology Center were genetically similar and compatible for management purposes, indicating that the Virgin River Program's woundfin genetic management program is successful. The results of that study also indicated that woundfin stocked previous to 2005 had contributed to wild recruitment in river. In 2007, the Virgin River Program funded a similar comparative analysis of captive versus wild Virgin River chub stocks.

2.3.1.4 Taxonomic Classification Or Changes In Nomenclature

In 1989 (54 FR 35305, August 24, 1989), the Virgin River chub was listed throughout its entire historical range (then described as the Virgin River from its original confluence with the Colorado River upstream to LaVerkin Creek near Hurricane, Utah) as an endangered subspecies (*Gila robusta seminuda*) of the roundtail chub *Gila robusta*. At the time of listing the USFWS recognized that a closely related form of Gila robusta (presumably an undescribed subspecies) was found in the Moapa (=Muddy) River in Nevada. The USFWS recognized that the population of chub in the Muddy River also had experienced declines in abundance and reduced range, but specifically stated that it was not affected by the 1989 listing. In 1992, a review of morphological and genetic characters was used to determine that the Virgin River chub, was in fact a full species, *Gila seminuda* (DeMarias et al. 1992), which served as the basis for the American Fisheries Society's recognition of full species ranking for Virgin River chub (Nelson et al. 2004). The USFWS recognized the same when critical habitat was designated. The same study determined that the chub found in the Muddy River was conspecific with *G. seminuda*. In 1995, the USFWS proposed a status review of the Virgin River chub population in the Muddy River, which was never completed (refer to section 1.3.3). A status review or candidate assessment should be pursued. If the Muddy River population is listed the Recovery Plan should be revised to include recovery planning activities and recovery criteria for the Virgin River chub in the Muddy River.

In the sixth and most recent version of the American Fisheries Society' publication of *Common and Scientific Names of Fishes from the United States, Canada, and Mexico* (Nelson et al. 2004) the common name for the chub found in the Virgin and Muddy Rivers is "Virgin chub." The USFWS considers "Virgin River chub" and "Virgin chub", to be synonymous and retains the usage of Virgin River chub.

2.3.1.5 Spatial Distribution, Trends In Spatial Distribution

When the woundfin was listed in 1970, they occupied 12.5% of their historical range. Thirty years later the USFWS designated that portion of historical range (87.5 miles of the Virgin River) as critical habitat. In the past 20 years, woundfin have been eliminated from at least 35 miles of critical habitat in the lower river and abundance has declined to precariously low levels elsewhere.

The spatial distribution of the Virgin River chub has changed little since it was listed in 1990 with populations persisting in two core areas (above Washington Fields Diversion in Utah, and near the confluence with Beaver Dam Wash in Arizona). However, more transient populations below the Mesquite Diversion and downstream from the Johnson Diversion in Utah to the Arizona border have been lost / reduced. Range within the Muddy River has shrunk since the 1970s, and now includes approximately 30 kilometers of river between the Warm Springs bridge and Wells Siding diversion. Surveys in 2007 detected several individual chub within the Warm Springs area, the first detection in that location since their extirpation by blue tilapia in 1997.

2.3.1.6 Habitat Or Ecosystem Conditions

Flows in the Virgin – Muddy River system were fully appropriated by the early 20th century. During those early years of settlement and as engineering practices improved, portions of the Virgin River main stem and the lower Muddy River became dewatered periodically. The majority of the present day threat to the endangered fish in terms of habitat destruction occurred between 80 and 100 years ago. Hoover Dam was completed in 1935 creating Lake Mead, which inundated the lower 80 kilometers (50 miles) of the Virgin River and the lower 8 kilometers (5 miles) of the Muddy River. Subsequent stocking of nonnative species (illicit or authorized) in Lake Mead to develop a sport fishery and their unrestricted access to the lower reaches of the Virgin and Muddy Rivers introduced a new threat to the Virgin River fishes. Additional water development projects on tributaries to the Virgin River (Santa Clara, Ash Creek, and Beaver Dam Wash) continued through the latter half of the 1900s. In recent times, the Quail Lake project (completed in 1985) and Sand Hollow Reservoir (completed in 2002) have replaced older diversion structures in the upper river and further modified Virgin River hydrology. Habitat conditions are further discussed in the Five Factor discussion below.

2.3.2 Five-Factor Analysis

2.3.2.1 Present Or Threatened Destruction, Modification Or Curtailment Of Its Habitat Or Range

Altered flow, sediment, and temperature regimes in regulated rivers have been implicated as 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). Deacon and Hardy (1984) surmised that irrigation diversion throughout the Virgin River system has a significant adverse effect on recruitment of woundfin, probably by reducing streamflow during the period of spawning, development of fry, and recruitment into the population.

In the upper Virgin River, the Hurricane and LaVerkin Ditch Diversions constructed in the late 1890s and early 1900s diverted Virgin River flows a short distance upstream of Pah Tempe Springs in LaVerkin, Utah. These diversions routinely dewatered the river downstream to Pah Tempe Springs under low flow conditions. Those structures remained in service until replaced by the Quail Creek Diversion in 1985. The Quail Creek pipeline capacity is approximately 125 cfs. These historical diversions and the current Quail Creek facilities had the capacity to periodically dry dam the Virgin River; however, current operations maintain a minimum flow of 3 cfs (Lentsch et al. 1995). Water use in the upper river has not changed appreciably since the Quail Lake Project was completed in 1985.

A portion of the flow diverted at the Quail Lake Diversion is returned to the river at various locations downstream. The first release (approximately 25 to 30 cfs) occurs just downstream from Pah Tempe Springs at the upstream terminus of critical habitat. The Quail Lake Project operations require a minimum flow of 86 cfs (or the natural flow as measured at the Virgin River gage at Virgin, Utah, if less than 86 cfs) to the Washington Fields Diversion.

The entire flow of the river has been diverted near the present site of the Washington Fields Diversion periodically since the early 1900s through authorized water rights. The Virgin River Program is currently developing a flow recommendation for the river downstream of Washington Fields Diversion in conjunction with operations of a recently constructed fish screen at the head of the irrigation canal (USFWS 2005b). Currently, a minimum flow of 5 cfs passes the Washington Fields Diversion through the operation of the fish screen. Irrigation returns restore a portion of the flow downstream of the diversion structure.

The Virgin River channel is a “losing” reach downstream of the Utah State line and may have dried periodically during pre-development times. Operations at the St. George City Water Treatment Plant downstream of Bloomington, Utah, in concert with Quail Creek Reservoir operations, have augmented summer base flows. These base flows now include more frequent surface flow through the Gorge than occurred through much of the 1900s. Increased land development and residential irrigation has led to return flows in previously dry tributary streams and increased flow in the river. Whereas, flow augmentation in this portion of the system helps to support local fish communities, it also has been implicated in the upstream expansion of red shiner.

A series of springs beginning in the lower Virgin River Gorge and extending downstream through Littlefield, Arizona, maintain baseflows near 50 cfs in the Virgin River near its confluence with Beaver Dam Wash. Three diversion structures in the lower 25 miles of the Virgin River capture substantial amounts of water during low flow periods including: the Mesquite Diversion (30 to 40 cfs); the Bunkerville Diversion (15 to 20 cfs); and the Riverside Diversion. During the recent period of drought, resource managers reported flows in the Mesquite Bridge and Riverside Reaches at less than 20 cfs and at times 0-5 cfs (Golden and Holden 2004). There are only two short reaches of critical habitat that are not heavily impacted by water development: the area immediately above the Washington Fields Diversion; and the area extending from the lower Virgin River Gorge to the Mesquite Diversion.

Holden et al. (2001) showed that fall woundfin abundance was significantly lower in drought years than in non-drought years. Golden and Holden (2002) found the same relationship applied to other Virgin River native fishes as well. Additionally, fall woundfin abundance was significantly lower in years where summer 50% exceedence flows were below 75 cfs (Holden et al. 2001). Fall woundfin abundance declines even further where summer 50% exceedence flows were below 50 cfs (Holden et al. 2001).

In addition to the obvious loss of habitat associated with diminished flow are effects associated with decreased turbidity and elevated summer temperatures. The effects of unnaturally low levels of turbidity are not completely understood, but appear to cause fish to crowd into habitats with cover, increasing competition for resources and predation. Researchers have shown that Virgin River fish experience physiological limitations and subsequent mortality at approximately 31°C (88°F) (Rehm et al. 2006). Deacon et al. (1987) observed the loss of equilibrium in Virgin River fishes when exposed to 31°C (88°F) and above, which he referred to as the critical thermal maxima Critical thermal maximum differ by species and acclimation conditions. Less well characterized but

perhaps of equal concern is a temperature at which behavior is affected; a behavioral thermal maximum. Field observations in the Virgin River indicate that at temperatures in excess of 28°C (82°F) native fish shift their behavior to seek out thermal refuge (deeper pools, groundwater inflows, etc) (Fridell and Morvilius 2005a, Morvilius-Auer and Fridell 2006). The temperature in the above Washington Fields Diversion reach, particularly from Quail Creek Reservoir upstream to Pah Tempe Springs, can be very high during the summer (peak daily temperature above 35°C (95°F), mean daily temperature greater than 29°C (84°F)) (Addley et al. 2005). Similarly in the lower river, Golden and Holden (2004) report that critical thermal maximum is often exceeded at the Riverside area and can even be exceeded near Beaver Dam Wash where there are large influxes of groundwater.

Reducing the threat of future exceedence of behavioral thermal maximum and critical thermal maximum will require innovative water management strategies. In 2004, the Washington County Water Conservancy District released approximately 10 cfs of cool water from their Kolob Reservoir from July 20 through the end of August. Those flows entered the river a short distance upstream of critical habitat. Fish sampling during Fall 2004 indicated over-summer survival that year was better than had been observed in preceding low flow years (Fridell and Morvilius 2005). The Utah Water Research Lab also has provided preliminary design analyses on use of a flow back pipeline from Sand Hollow Reservoir to the confluence area that would extend the area of beneficial thermal influence now confined to the river below Stratton Pond. The Virgin River Program has identified the need to improve habitat quality through the critical summer period a top priority. As a similar coalition is established in the lower river, protection of summer habitat conditions (even more problematical from a water management perspective) must be made a priority there as well.

An unquantified, but real threat to the Virgin River fish is their entrainment at water diversion structures throughout the Virgin River system. The Quail Creek Diversion takes the largest amount of water in the Virgin River system, but is located upstream of designated critical habitat (and occupied habitat) for the endangered fish. The next diversion structure downstream, the Washington Fields Diversion, is the second largest in terms of depletion, and has the capability to dry dam the river. This diversion, which demarcates the downstream terminus of the largest remaining population of woundfin and Virgin River chub, was likely responsible for entrainment of endangered fish annually. The Washington Fields Diversion was the first structure targeted for remediation. In 2005, the Washington County Water Conservancy District, the Washington Canal Company and the Virgin River Program completed construction of a fish screen at the head of the irrigation canal, which shunts fish back to

the Virgin River immediately downstream of the diversion structure (USFWS 2005b). The construction of this fish screen and the restoration of perennial flow downstream of the Washington Fields Diversion is probably the most successful accomplishment and important recovery activity that has occurred to date in the Virgin River system. Entrainment of Virgin River fish at diversion structures farther downstream (Mesquite, Bunkerville, and Riverside) remains unresolved.

Another factor limiting native fish population in the upper river was the periodic release of sediment that had accumulated behind the Quail Creek Diversion dam (sediment sluicing). Depending on the age of the accumulated sediments, the associated biological oxygen demand and / or sediment oxygen demand could be very high. In the autumn 2003, a sluicing event resulted in depressed dissolved oxygen levels and a subsequent fish kill in the upper river. The Washington County Water Conservancy District recognized that, depending on the circumstances, sluicing could be a threat to the recovery of the Virgin River fish and quickly contracted with a private consultant to develop a sediment management plan (BIO / WEST 2004). That plan, which is based on a model that tracks the amount of sediment accumulating behind the dam (based on U.S. Geological Survey sediment transport data) predicts the quantity of natural stream flow necessary to safely sluice; basically the greater the accumulation of sediment the greater natural stream flow required to safely transport it downstream. In 2005, the USFWS consulted with the U.S. Army Corps of Engineers on the implementation of that plan as a condition of the Washington County Water Conservancy District Quail Creek permit (USFWS 2005c). Proper implementation of the management plan coupled with a standardized monitoring protocol (fish and water quality) has proven to greatly reduce the threat associated with sediment sluicing.

Tamarisk was introduced into the United States from central Asia in the 1830s to stabilize river banks, as a windbreak and as an ornamental plant. This nonnative has taken over the riparian zone / floodplain of the Virgin River system, especially in low gradient areas with sandy substrates. The tree is tolerant of drought, heat, cold, salinity, fire and flooding. Its roots extend deeper than many riparian plants, thus it can out compete other plants and grow in areas where water is not readily available. The tree can sprout from roots or from branches. Tamarisk occurrences in the Virgin River drainage range from vast monotypic stands to individual trees interspersed within native vegetation, and also as isolated trees and stands in upland areas, where springs or moist soil conditions may be present. Tamarisk can dominate floodplain vegetation and can influence normal river function. Stream channels become restricted and flood flows may cut new channels due to the thick growth or because of tamarisk debris dams. The tree (particularly when in monoculture) impacts native fish

habitat and is less desirable for other wildlife such as mammals and birds including the endangered southwestern willow flycatcher (*Empidonax trailii extimus*). Tamarisk control efforts have begun throughout the Virgin River system. To date, the impetus behind tamarisk control efforts has been to reduce potential fire fuels near wild land / urban interfaces. Large scale tamarisk treatment projects coupled with native revegetation efforts have occurred near the City of Mesquite and downstream toward Halfway Wash by the Bureau of Land Management and National Park Service. Efforts have mainly focused on the higher, less saturated terraces of the floodplain where tamarisk has a stronghold. In treatment areas near the active river channel, a river side fringe (30 feet wide) of tamarisk and native vegetation has been left untouched to minimize effects to the aquatic environment, including the Virgin River fish. Important nesting areas for the southwestern willow flycatcher in the lower river have not yet been treated.

High flows in 2005 were of sufficient scale that large thickets of tamarisk were removed along the Virgin River main stem and in its tributaries. Efforts have been made to take advantage of the flood induced reset by re-vegetating post flood point bars with native coyote willow. However, shifting the system away from tamarisk as the dominant species will require constant effort.

Population growth in the riverside communities of St. George, Utah, and Mesquite, Nevada, has outpaced national averages for decades. At current growth rates, water demand projections for the City of St. George suggest available resources will be depleted by the year 2020. A proposed 160-mile pipeline from Lake Powell to Washington County, Utah, could supply as much as 70,000 acre feet of water annually for municipal and industrial use in the upper Virgin River drainage. At the time of this review, the Lake Powell pipeline project has entered a preliminary design phase. Based on the level of congressional support, this project has a high likelihood of occurring. Potential effects to the Virgin River fish associated with a trans-drainage diversion and the inter-related population growth include: increased urban runoff; more infrastructure (increased encroachment on river and floodplain for transportation and utility conveyance); more recreational activity in the floodplain; potential introduction of non native species. However, with this project comes some potential to assist in the recovery of endangered fish by trading out current consumptive uses of Virgin River surface flows with the imported water. It is too early to tell how much room for recovery actions there is in this project.

Due to the continued growth in Mesquite, Nevada, and potential growth in other adjacent communities such as Bunkerville, the VRHCRP in the lower river intends to implement a Hydrologic Monitoring and Mitigation

Plan for the Virgin River Basin, Nevada, to monitor the interaction between Virgin River surface flows and groundwater development. The plan was developed in late 2006 and implementation should occur in 2008 directed by the participants in the VRHCRP. If data and analyses demonstrate that surface water flows are being depleted due to groundwater pumping, and thereby affecting threatened or endangered species inhabiting the river and riparian corridor of the Virgin River floodplain, such as the Virgin River fish, appropriate mitigation would be implemented as part of the VRHCRP. There also is the potential in Nevada for entities to develop existing water rights of Virgin River surface water to satisfy water demands. Both the Virgin Valley Water District (water purveyor in Mesquite and northeast Clark County, Nevada) and the Southern Nevada Water Authority (seven-member agency managing water resources for the Las Vegas Valley) hold numerous water rights for Virgin River surface waters. It is incumbent upon the USFWS and the Virgin River Program(s) to work with the project proponents to ensure that preservation of the fragile ecosystem of the Virgin River is fully recognized as the Lake Powell pipeline project, and other water projects, are developed.

2.3.2.2 Overutilization For Commercial, Recreational, Scientific, Or Educational Purposes

This is not considered a threat to the recovery of the Virgin River fish.

2.3.2.3 Disease Or Predation

Introduction and establishment of nonnative fish in western rivers of the USA is a major threat to conservation of native fish assemblages (Minckley and Deacon 1968, Stanford and Ward 1986, Moyle et al. 1986, Carlson and Muth 1989, Minckley and Deacon 1991, Olden et al. 2006).

As recognized in the Recovery Plan, the introduction of nonnative fish species, in particular the red shiner has had detrimental impacts on native fish populations in the Virgin River system. Note: Predation of juvenile or adult fish also are likely a factor, especially when the fish are in limited thermal refuges concentrated in with centrarchids and catfish. This is probably most problematic in the lower river where there are smaller pools and any cover is dominated by predatory nonnative fish. Negative interactions between native species and small bodied nonnatives (red shiner, sand shiner (*Notropis straminues*), and fathead minnow (*Pimephales promelas*)) have been documented throughout the Colorado River basin (Haines and Tyus 1990, Rupert et al. 1993, Propst and Gido 2004).

Cross (1975) noted that red shiner, which was likely introduced into the Lower Colorado River as a baitfish (Miller 1952), was common to abundant below Mesquite, Nevada, during his surveys. Red shiner were found in the Virgin River in Utah in 1984, their expansion upstream likely due to the record high flows of 1983 (Deacon 1988). Resulting declines in Virgin River chub and woundfin numbers are caused by predation of young of year, competition for habitat and food resources, and introduction of parasitic organisms (Heckman et al. 1986).

Currently, the only area free of red shiner within the geographic distribution of woundfin and Virgin River chub is located in the Virgin River above Washington Fields Diversion in Utah. This stretch of the river was compromised by red shiner one time in the spring of 2002; fortunately red shiner were successfully eradicated from this stretch with a rapid response and massive mechanical (seining) removal effort (Fridell et al. 2003). The reach immediately below Washington Fields Diversion downstream to the Johnson Diversion, is currently being maintained as a buffer zone against the upstream spread of red shiner. Rotenone treatments of the Virgin River have been conducted since 1988 to maintain this buffer (Comella and Fridell 1998, Fridell et al. 2004). It is critical to maintain this buffer zone to ensure the continued existence of woundfin and Virgin River chub within the Virgin River system. The eradication program goals outlined in the Virgin River Program document include the systematic removal of red shiner through the implementation of five chemical treatment phases: Phase 1) treatment between the Washington Fields Diversion and Johnson Diversion; Phase 2) treatment of the Washington Fields irrigation canals; Phase 3) treatment of the Fort Pearce Wash; Phase 4) Treatment between Johnson Diversion and Webb Hill fish barrier; Phase 5) treatment from the Webb Hill fish barrier to the Utah / Arizona border barrier. This design partitions problem reaches into manageable units so eradication efforts can be conducted in an efficient, stepwise, downstream fashion. Multiple treatments are planned for each phase, and treatments are repeated as necessary (Comella and Fridell 1998).

Unfortunately, red shiner treatments have become even more complicated in recent years. In response to flood damage that occurred during January 2005, the Natural Resource Conservation Service responded with a large scale stream bank stabilization project conducted under their Emergency Watershed Protection Program. From March 2005 through December 2006, several miles of peaked stone dikes (rock revetment) were constructed along the banks of the Virgin and Santa Clara Rivers and Ash and LaVerkin Creeks to protect Washington County residents and their property from a flood of similar magnitude in the future. Unexpectedly, resource managers have identified locations along the constructed rock walls where water is released to the river channel. The

origin of the flow is not well understood. River flow may be piping along the axis of the wall from a point upstream (some segments of wall are in excess of a mile long), or the construction process may have consolidated groundwater seeps. Regardless of the origin, these freshwater outflows provided refuge for a number of species including red shiner during the most recent rotenone treatment (Mr. Richard Fridell, UDWR, pers. comm., November 2006). Successful use of rotenone is a complicated management strategy in any system; the Virgin River with its associated marsh habitats and irrigation return canals makes this situation particularly complex. It is unclear if the added complexity associated with these new fresh water sources will factor in all future treatment efforts.

In the lower river, red shiner have been mechanically (seining) removed from stretches of river prior to the release of hatchery raised woundfin. Results of those efforts indicate that periodic removal can be effective under proper environmental conditions, but the effect is short-term. Lake Mead will always be a source of red shiner and other nonnative species. Therefore, Virgin River resource managers have promoted a “top down” approach; i.e., construct an adequate number of barriers throughout the system and then push (sequential rotenone treatments) red shiner back toward the lake. This buffer zone concept, which currently extends all the way upstream to the base of the Washington Fields Diversion in Utah, must be expanded downriver. The Virgin River Program is currently pursuing construction of a barrier in the Virgin River Gorge in Arizona, which is a positive extension of the existing barrier system in Utah. The Lower Virgin River Recovery Implementation Team is currently pursuing a double-barrier system near the lower end of critical habitat at Halfway Wash. Additional barriers (either new structures or revamped existing ones) will likely be required in the intervening reach. Effective nonnative fish barriers will always be an important tool in protecting against upstream expansion of red shiner, and other nonnative species, from Lake Mead. In the very long-term, resource managers and land management agencies hope that some of the barriers could be decommissioned.

Other nonnative species (black bullhead, channel catfish, largemouth bass, bluegill, green sunfish, common carp , mosquitofish, and blue tilapia) pose additional threats to Virgin River fish recovery in the lower river (Albrecht et al. 2007). Golden and Holden (2002) showed the potential for some of these species to impact upper river populations as well. The expansion and increased abundance of blue tilapia in the Muddy River system was implicated in the decline of Virgin River chub population from 1995 to 1998 in that system (Scoppettone et al. 1998). The Bureau of Land Management working with a coalition of resource managers (Nevada Division of Wildlife and others) recently constructed a nonnative fish barrier in the Muddy River system to protect remaining native fish

populations and to assist in future recovery actions. Continued efforts to control red shiner will likely reduce the effect of these other nonnative species as well.

Introduced parasites have been found in woundfin and Virgin River chub (Heckmann et al. 1986, 1987), but they are not currently considered a factor in the decline of these species (USFWS 1995).

2.3.2.4 Inadequacy Of Existing Regulatory Mechanisms

There is a long history of anthropogenic activity in the Virgin River system that has negatively affected the Virgin River fishes. As discussed above, these activities can be generally categorized as either water development and floodplain encroachment related or those associated with the introduction of nonnative species. To offset those negative effects a variety of recovery efforts have been organized throughout the basin. Below we discuss specific actions conducted by the Recovery Team, the Lower Virgin River Recovery Implementation Team, and in recent years by the Virgin River Program to offset those effects.

The amount of damage to personal and public property that occurred during the January 2005 flood was the impetus for a monumental streambank stabilization program recently completed in Washington County, Utah (USFWS 2005d). The long-term effect on channel dynamics from placement of the revetment structures is unknown; the unforeseen implications to future red shiner removal efforts were discussed above. County and City planners will need to ensure that the bank stabilization projects do not have the reverse effect; increased development as result of a false sense of security. To head off further floodplain encroachment, communities along the Virgin River corridor must adopt and enforce floodplain and, where appropriate, erosion zone ordinances (refer to Natural Channel Designs 2005a, 2005b for guidance).

Human population growth in Washington County, Utah, and Lincoln County, Nevada, impacts the Virgin River corridor. Old bridges are constantly being repaired, new bridges are being constructed, and utility lines that cross the river need to be upgraded or new lines need to be placed. The States of Utah, Arizona, and Nevada are hard pressed to fully process each Stream Alteration Permit application that comes in. The USFWS Ecological Services Offices in Salt Lake City, Utah, and Las Vegas, Nevada, must be vigilant to keep themselves apprised of any proposed action that could affect the fish directly or modify critical habitat. These projects are typically subject to Section 7 because of a Federal nexus with the U.S. Army Corps of Engineers through their Clean Water Act permitting process. However, projects further removed from the wetted channel are not always considered jurisdictional by the U.S.

Army Corps of Engineers. The Federal and State regulatory agencies must work with the local communities at the Master Planning stages to ensure that the effects of proposed development on the endangered fish and other listed and non-listed plants and animal species are considered.

It is important that State wildlife agencies and their Federal partners continue to actively pursue measures to prevent nonnative fish (sport fish and other species) escapement from impoundments that connect to the Virgin River and its tributaries. The States of Utah, Arizona, and Nevada must continue to support endangered species recovery efforts within their boundaries including nonnative fish control and stocking.

The Virgin River Fishes Recovery Team must remain active, particularly as a coordinated Section 7 / 10 Program is being established for the lower Virgin River. The Virgin River Programs need to communicate with each other as well as other recognized conservation groups, namely the Washington County HCP and the Lincoln County HCP to avoid duplication or conflicting efforts at a minimum, but to promote coordinated ecosystem conservation and recovery in the long term.

The Lower Virgin River Recovery Implementation Team is an action-oriented branch of the Recovery Team focused on issues in the lower river (Arizona and Nevada). The Lower Virgin River Recovery Implementation Team has drafted a strategy to assist in the recovery of a variety of species and habitats along the Virgin River. This team implements and coordinates conservation actions for woundfin, Virgin River chub, Virgin spinedace *(Lepidomeda mollispinis)*, desert sucker *(Catostomus clarki)*, and flannelmouth sucker *(Catostomus latipinnis)*. The USFWS chairs this team comprised of representatives from: Southern Nevada Water Authority, Bureau of Land Management, National Park Service, Nevada Division of Wildlife, Arizona Game and Fish Department, and U.S. Bureau of Reclamation. Not as well funded as the Virgin River Program, this group has concentrated on: implementing a long-term monitoring program for native fish in the lower river; studying the effect of mechanical removal of red shiner on native fish populations; studying red shiner / woundfin interactions; developing hatchery-reared woundfin stocking protocols; and monitoring the advancement of other nonnative species (blue tilapia, striped bass, etc.) from Lake Mead into the Virgin River.

The Virgin River Program was formally established on January 5, 2002. The goals of the program are to protect and recover listed and sensitive fish species in the Virgin River while ensuring that new and historical water uses are protected throughout the basin. The Virgin River Program was developed by the UDWR, USFWS, Bureau of Land Management, National Park Service, and Washington County Water Conservancy

District with assistance from conservation organizations and the Utah Water Research Laboratory. These agencies and organizations began working cooperatively in 1995 to develop a program that would promote recovery of imperiled aquatic species and assist in meeting the growing need for water by industrial and municipal water users in the Virgin River Basin. The Virgin River Program coordinates, directs, and funds recovery actions for listed species (woundfin, Virgin River chub, and the southwestern willow flycatcher). The Virgin River Program also expedites management actions taken to promote conservation of the following State sensitive species: Virgin spinedace, flannelmouth sucker, desert sucker, speckled dace, and southwestern toad. The Program consists of eight elements: 1) Complete description of baseline elements; 2) Provide and protect instream flows; 3) Protect and enhance aquatic, riparian and 100-year floodplain habitat; 4) Protect and enhance native species communities; 5) Maintain genetically appropriate brood stocks; 6) Determine ecologically limiting factors; 7) Monitor habitat conditions and populations of native species; and 8) Improve education and communication on resource issues. The Virgin River Program has an annual operating budget of approximately $2 million.

Other Conservation Efforts in the Virgin River Basin Include:

The Washington County Habitat Conservation Plan - In 1996, to resolve conflicts between development pressures and the conservation of the desert tortoise, (*Gopherus agassizii*) (Mojave population), the USFWS issued the Washington County Commission a 20-year, county-wide permit for incidental take of the tortoise in accordance with the county's approved Habitat Conservation Plan (HCP). Since that time, in excess of 8,000 acres of the Virgin River drainage have been added (either through acquisition or land transfers) to the nearly 60,000-acre Red Cliffs Reserve. Partners in the Program include Bureau of Land Management, Utah Department of Natural Resources, and other local entities. Conservation actions include annual population monitoring and land management (grazing, mining, and recreation).

The Virgin River Watershed Management Plan – Developed by the Washington County Water Conservancy District in cooperation with a variety of local interests, the Virgin River Watershed Management Plan process was initiated in 1998 by the Virgin River Management Plan Coordinating Committee. The original purpose was very broad in scope and included: improved communications for watershed issues, development of information opportunities for the public, providing water resources to meet the county's needs, addressing habitat improvement for endangered species, improving water quality, etc. The current plan provides more direction to developers and focuses on specific resource issues on a sub-basin level. The plan in its entirety can be found at: http://wcwcd.state.ut.us.

Virgin River Conservation Partnership - This group of 20+ organizations in southern Nevada and northern Arizona represents the diverse interests in the lower Virgin River and adjacent areas who are working together to strike a balance between conservation and growth in the Virgin River corridor. Their mission is to balance conservation and restoration of the Virgin River ecosystem with economic development – while promoting ecological sustainability, economic viability, responsible use, stewardship, and long-term community benefit. Their vision is a restored, protected Virgin River ecosystem realized through collaborative planning and management, and community-based action. The group meets regularly to share information and discuss projects, efforts, and issues related to the Virgin River.

Pending Conservation Efforts Include:

Lower Colorado Multi-Species Conservation Plan - This multiple species conservation program, enacted in October 2005, covers the main stem of the Lower Colorado River from Glen Canyon Dam in Arizona to the southerly international boundary, near San Luis, Rio Colorado, Mexico, including the 100-year floodplain. It is designed to ensure the survival of 27 species through restoration of wildlife habitat along the lower Colorado River, including 8,132 acres of riparian, marsh and backwater habitat for 6 federally protected species and at least 20 other species that are native to the river system. The plan includes 6 State agencies, 6 Tribes, 36 cities and water and power authorities, and 6 Federal agencies. Some of the conservation measures required under this Plan may be located in the Virgin River Basin.

Proposed Virgin River Habitat Conservation and Recovery Program - A coordinated effort has been proposed for the protection of species listed as endangered under ESA while meeting the demands of population growth, by resource management agencies and several other interested entities in the lower Virgin River basin in Nevada. This effort was initiated as a result of ESA requirements associated with Federal land sales in Mesquite, Nevada. In addition, resource managers in Nevada recognized the need to merge listed species conservation efforts being conducted by multiple parties into a single collaborative process to maximize protections afforded the species and habitat by making the most efficient use of time and resources. The VRHCRP will develop, fund, and implement conservation actions for listed species and their habitat along the Virgin River, and contribute to the long-term recovery and conservation of listed species. Some of these conservation actions will be necessary to offset impacts from proposed development actions. The VRHCRP also will aid in the conservation of other species in the lower Virgin River that are, or might become, candidates for listing as threatened or endangered species under ESA. The VRHCRP is designed to address both sections 7 and 10

of the ESA. An Executive Committee who directs the VRHCRP is comprised of representatives from the USFWS, Bureau of Land Management, National Park Service, Nevada Division of Wildlife, City of Mesquite, Clark County, Virgin Valley Water District, and Southern Nevada Water Authority. They rely upon technical expertise from the Lower Virgin River Recovery Implementation Team, wildlife biologists, and hydrologists to provide technical guidance and recommendations. The VRHCRP intends to continue coordination with the Virgin River Program, to build upon and augment their successes in the upper river. It is critical that this proposed counterpart to the Virgin River Program be established and become functional in the near future. Recovery of the endangered Virgin River fish must be actively pursued throughout critical habitat to ensure a reasonable chance of success.

Virgin River Basin Resource Conservation Assessment - In 2003, Clark County approved and funded a proposal submitted by the National Park Service and Bureau of Land Management to conduct an assessment of resource conservation needs in the lower Virgin River Basin in Nevada. The resulting species conservation-based technical effort, when completed, will provide information for use as a cooperative strategic planning tool. The assessment will analyze and prioritize conservation actions for more than 50 potentially imperiled species in the Virgin River Basin. The Virgin River Basin Resource Conservation Assessment is being conducted in coordination with the VRHCRP in the lower Virgin River.

2.3.2.5 Other Natural Or Manmade Factors Affecting Its Continued Existence

According to the Intergovernmental Panel on Climate Change (IPCC) (2007, p. 1) "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1,300 years (IPCC 2007). It is very likely that over the past 50 years: cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007). It is likely that: heat waves have become more frequent over most land areas, and the frequency of heavy precipitation events has increased over most areas (IPCC 2007).

The IPCC (2007) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next 2 decades a warming of about 0.2°C (0.4°F)

per decade is projected (IPCC 2007). Afterward, temperature projections increasingly depend on specific emission scenarios (IPCC 2007). Various emissions scenarios suggest that by the end of the 21st century, average global temperatures are expected to increase 0.6 to 4.0°C (1.1 to 7.2°F) with the greatest warming expected over land (IPCC 2007). Localized projections suggest the southwest may experience among the greatest temperature increase of any area in the lower 48 States (IPCC 2007). The IPCC says it is very likely hot extremes, heat waves, and heavy precipitation will increase in frequency (IPCC 2007). There also is high confidence that many semi-arid areas like the western United States will suffer a decrease in water resources due to climate change (IPCC 2007).

Certain aspects of the hydrology and water-supply of the Colorado River System are extremely sensitive to climate change that could occur over the next several decades (Nash and Gleick 1993, Christensen et al. 2004). Recent and ongoing drought conditions in the Upper Colorado River Basin have resulted in less than normal precipitation and reduced streamflows through most of the basin. Climate change is of particular concern in the Colorado River System because of the sensitivity of the snow accumulation processes that dominate runoff generation, and because of a high water demand relative to supply (Loaiciga et al. 1996).

Increases in temperature of 2°C (4°F) with no change in precipitation are predicted to cause mean annual runoff of the Colorado River to decline by 4 to 12% (Nash and Gleick 1993). The temperature-related effects on streamflows also include an increase in winter runoff from an increased rain to snow ratio, as well as an earlier and faster spring snowmelt, and a decrease in summer runoff (Wolock and McCabe 1999). Natural streamflow of the Colorado River System by the mid 21st century is expected to decline between 6% (Christensen and Lettenmaier 2006) and 45% (Hoerling and Eischeid 2007).

In the preceding sections we have discussed the effects of diminished stream flows, particularly during the base flow period, and the resulting elevated temperatures to the endangered Virgin River fishes. Throughout designated critical habitat critical thermal maximum and behavioral thermal maximum for woundfin have been and continue to be exceeded for varying periods of time in most years. We can only assume that the predicted changes documented in the IPCC reports will exacerbate already highly stressful conditions during drier years. Still, considerable uncertainty remains concerning the accuracy of these global models to localized areas. It is unlikely climate change will have any effect on nonnative fish invasions.

It is difficult to identify when and how climate change impacts will be addressed with specific actions. Therefore, it is incumbent upon management agencies to consider the range of predicted effects associated

with climate change in their assessment and management of threats. The Virgin River Programs will need to minimize or remove threats, monitor populations, and evaluate responses as necessary to insure recovery under the principles of adaptive management. This process must take into consideration those changes that may occur as a result of climate change.

2.4 SYNTHESIS

In summary, over the course of the past 30 years, woundfin have generally declined throughout their occupied range and critical habitat. They have been extirpated from the Lower Virgin River (i.e., from Beaver Dam Wash, perhaps from the Utah / Arizona State line, downstream to Lake Mead). Populations in Utah, particularly those upstream of the influence of red shiner (i.e., upstream of the Washington Fields Diversion), have persisted better than anywhere else. Preventing the spread of red shiner upstream of Washington Fields Diversion has been a constant effort. Without it, we assume the entire wild population of woundfin would have been lost.

Reduced base flows are of equal concern and likely threaten woundfin to varying degrees throughout critical habitat. The effects of reduced flows, exacerbated by the severe and persistent drought in recent times (the lowest Virgin River flows on record occurred in 2002), have negatively affected woundfin and other native species throughout the Virgin River, including the population upstream of Washington Fields Diversion. Fortunately, the wild population of woundfin upstream of the Washington Fields Diversion appears to have been sufficiently resilient to exhibit a strong reproductive response during 2005, when wetter conditions prevailed. However, reproduction occurred late that year; therefore, resource managers are uncertain if the positive population response witnessed in 2005 will have a lasting effect.

Recovery Team monitoring was designed to target small-bodied fish and, therefore, is somewhat limited in its ability to track trends in the Virgin River chub population. It does provide an important index of chub population dynamics in that it characterizes abundance of young of the year and juvenile Virgin River chub. Through a separate effort, resource managers have concluded that a total population estimate would require a huge amount of effort and may induce unacceptable levels of stress. The Virgin River Program and the Lower Virgin River Recovery Implementation Team are developing a catch effort based monitoring program. Virgin River chub are specific in their habitat selection (pools, fast runs with larger-sized substrates) and, therefore, are distributed differently than woundfin throughout the Virgin River system. Virgin River chub are more long-lived than woundfin, which likely explains the relative stability of their populations. We presume the reason Virgin River chub are less abundant at Beaver Dam Wash than in Utah is in large part due to negative interactions with nonnative species, primarily red shiner. However, Virgin River chub have persisted, albeit at relatively low abundances, where red shiner is a sympatric

species; woundfin have not.

The Recovery Team recognizes the primary threats to the Virgin River Fishes as competition and predation from nonnative species (primarily red shiner) and degraded habitat conditions (reduced flow / high temperatures). The Recovery Plan was revised in 1995, at which time only 16 miles of critical habitat above the Washington Field Diversion in Utah were free of red shiner. At that time, significant effort (mechanical and chemical) had been expended to protect these upper reaches of critical habitat. Since that time, maintenance of the 16-mile red shiner free zone has required monumental efforts and the threat of red shiner expansion remains as prevalent today as it was in the late 1980s when red shiner became established in the upper river. Red shiner and woundfin cannot co-exist. Red shiner must be eliminated from each portion of its range before any change in status would be considered. Habitat conditions throughout critical habitat, with the possible exception of two short stretches (a. between the Quail Creek Reservoir release point and the Washington Fields Diversion in Utah; and b. the portion of the lower river influenced by the spring flow near Littlefield, Arizona) are compromised during the summer months in most years, but particularly during low water years. Critical and behavioral thermal maxima are exceeded for varying periods of time in most years. The Virgin River Program (s) will need to find a reliable means of ameliorating these stressful conditions or our ability to recover these species will remain compromised.

Based on our review of current threats to woundfin and the Virgin River chub and in consideration of 30+ years (1976-2006) of monitoring information it is our opinion that there is no basis for a change in their current ESA listing status as endangered.

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

Woundfin priority number should be changed from “1” to “1C.” In addition to facing a high degree of threat and having a high recovery potential, this monotypic genus is in conflict with construction or other development or other forms of economic activity. This species, like the Virgin River chub, faces potential conflict between needed recovery actions and economic activities.

The Virgin River chub currently retains is Recovery Priority Number of 2C.

3.3 Listing and Reclassification Priority Number

N/A

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Endangered Species Listing (Section 4)

- USFWS should conduct a status review or candidate assessment of the Virgin River chub population in the Muddy River, in Nevada.
- If, the Virgin River chub population in the Muddy River, Nevada, is listed as threatened or endangered the Recovery Plan should be revised to address specific recovery actions and down- and delisting criteria for that population.

Habitat Restoration

- Upstream of Washington Fields Diversion to Pah Tempe Springs, base flows must be augmented to provide the flows and temperatures needed to assist in the recovery of the woundfin and Virgin River chub.
- In the short term, provide flows below the Washington Fields Diversion in a quantity that assists in the recovery of the Virgin River fish. In the long term, provide flows in a quantity that assist in recovery of the Virgin River fish throughout critical habitat.
- Continue to coordinate with State and Local governments in the development and implementation of floodplain and erosion zone ordinances throughout the Virgin River drainage.

Nonnative Fish Control

- Complete construction of a proposed nonnative fish barrier in the Virgin River Gorge in Arizona by the fall of 2008; extend Virgin River Program red shiner eradication
- Implement an effective nonnative control strategy downstream of the Virgin Gorge Barrier by autumn 2009.
- Complete construction of a proposed nonnative fish barrier in the lower Virgin River in Nevada by spring 2010.
- Prior to the next 5-year review, the USFWS should coordinate with State wildlife management agencies to develop a strategy to prevent further invasions of nonnative aquatic species (fish and mollusks) throughout the Virgin River drainage.

Policy

- Implement the proposed VRHCRP within 18 months of the signing of this 5-year review. A coordinated and consistently funded recovery effort in the lower river, as budgets allow, is required to compliment the activities of the Virgin River Program in the upper river.
- Work with stakeholders in Arizona to partner with the Virgin River Program, and with the VRHCRP when established, to fully incorporate occupied, and federally designated Critical Habitats into coordinated recovery actions.

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5.1. Personal Communications

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Woundfin and Virgin River Chub

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_x_ No change needed

Review Conducted By: Tom Chart, Utah Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve: _____ Date: 3/25/08
for Larry Crist, Field Supervisor, Utah Field Office

REGIONAL OFFICE APPROVAL:

Lead Regional Director, U.S. Fish and Wildlife Service

Approve: _____ Date: 3/30/08
Steve Guertin, Regional Director, Region 6

Cooperating Assistant Regional Director, Region 2, U.S. Fish and Wildlife Service

_✓_ Concur ____ Do Not Concur

Signature _____ Date 4/29/08

Acting

Cooperating Regional Director, Region 8/CNO, U.S. Fish and Wildlife Service

_✓_ Concur ____ Do Not Concur

Signature _____ Date 5/1/08

APPENDIX A

Summary Of Peer Review For The 5-Year Review Of Woundfin and Virgin River Chub

A. Peer Review Method

General: On April 7, 2006, the USFWS announced the initiation of a 5-year review for the woundfin and Virgin River chub and requested submission of any new information (71 FR 17900). In the summer of 2007 we initiated peer review of the science relevant to the draft Woundfin and Virgin River chub 5-year review and our use of said science. At an April 2007 meeting of the Virgin River Fishes Recovery Team we solicited nominations for potential peer reviewers. We requested they consider specific criteria (bulleted below) for any potential nomination.

- Expertise: The reviewer should have knowledge, experience, and skills in one or more of the following areas: Woundfin and Virgin River chub or similar species biology; conservation biology; small and declining population dynamics and extinction risk analysis; land development and use, invasive species, and other environmental pressures within the range of these species; land planning and management; modeling; and / or evaluation of biological plausibility.
- Independence: The reviewer should not be employed by the USFWS or other agencies within the Department of Interior. Academic and consulting scientists should have sufficient independence from the USFWS or Department if the government supports their work.
- Objectivity: The reviewer should be recognized by his or her peers as being objective, open-minded, and thoughtful. In addition, the reviewer should be comfortable sharing his or her knowledge and perspectives and openly identifying his or her knowledge gaps.
- Advocacy: The reviewer should not be known or recognized for an affiliation with an advocacy position regarding the protection pallid sturgeon under the ESA.
- Conflict of Interest: The reviewer should not have any financial or other interest that conflicts or that could impair his or her objectivity or create an unfair competitive advantage.

Their general recommendation was to contact members of the Desert Fishes Council for their experience with recovery of desert fishes, but perhaps not directly affiliation with Virgin River fishes recovery.

We solicited reviews from six qualified experts, and received a positive response from four. In a cover letter and attachments dated, July 18, 2007, we provided each peer reviewer with information explaining his or her role and instructions for fulfilling that role, the draft 5-year review including a full list of citations. The purpose of seeking independent peer review was to ensure use of the best scientific and commercial information available and to ensure and to maximize the quality, objectivity, utility, and

integrity of the information upon which the draft 5-year review is based, as well as to ensure that reviews by recognized experts were incorporated into the final document. Peer reviewers provided individual, written responses to the USFWS. Peer reviewers were advised that their reviews, including their names and affiliations, would (1) be included in the official record for this review, and (2) once all reviews are completed, would be available to the public upon request. Peer reviewer were instructed to contact Tom Chart, at the Utah Field Station (801-975-3330, Tom_Chart@fws.gov) for more information.

B. Peer Review Charge

The charge to the reviewers was to review the science relevant to the 5-year review and our use of said science, focusing their review on identifying and characterizing scientific uncertainties. Peer reviewers were asked not to provide advice on policy. Additionally, peer reviewers were asked to consider the following questions and to provide any other relevant comments, criticisms, or thoughts:

1) Is our description and analysis of the biology, habitat, population trends, historic and current distribution of the species accurate?

2) Does the 5-year review provide accurate and adequate review and analysis of the factors affecting the species (habitat loss and modification, overutilization, disease, predation, existing regulatory mechanisms)?

3) Are our assumptions and definitions of suitable habitat logical and adequate?

4) Are there any significant oversights, omissions or inconsistencies in the 5-year review?

5) Are our conclusions logical and supported by the evidence we provide?

6) Did we include all necessary and pertinent literature to support our assumptions andconclusions?

C. Peer Review Comments and *Responses*

Dr. David Propst's comments (received in letter format at the USFWS, Utah Field Office on August 17, 2007):

1) Very little information was provided on biology and habitat of either species, but reference is made to recovery plans that have more. Little snippets of biological information are scattered throughout document. Perhaps a paragraph or two describing biology and habitat associations of each would be helpful. This would also be a good place to cite published literature on species. It really is frustrating to review a summary document and have no ready access to the key reports upon which a review is based. A fair amount of information on population trends and historical distribution is presented, but this has to be accepted on faith as primary sources were not available. Graphs presenting population data for each site and tables

summarizing key information would be very helpful. *Response – We have included a more complete list of biology and life history references for both species, which was updated from the Recovery Plan. We cannot argue that the inclusion of some of the background information on these two species would make for a better and more complete story, but our thought was this was one instance where reference to existing documents was appropriate. Since, Recovery Plans are readily available via the Internet, we provided a web link to that document in addition to the literature citation. We tried to use peer reviewed literature as it applies directly to Virgin River literature when available. However, much of the available information is in agency report format, much of which is thankfully in very good shape. We agree with the reviewer's comment here and elsewhere that we fell short of drawing on the body of peer reviewed literature that speaks generally to threats (habitat alteration and nonnative interactions) to endangered fish in the American Southwest. We have pulled more of that discussion into this final version (look for it in the threats section). We also have included a reference map and graphs to depict trend is CPE at the four monitoring sites.*

2) A considerable amount of text is devoted to factors affecting status of each species and all seems reasonable. This is another area where reference to key published literature would bolster document. While I have no reason to doubt that diminished flows adversely affect each species, a graph or two illustrating such would be helpful. *Response – see above. The Virgin River system is relatively unregulated, i.e., the amount of storage capacity in the system is small; therefore, snow melt and runoff peaks are not greatly affected. The point made in the review is that baseflow have been reduced to the point of no surface flow in sections of the basins particularly during dry periods. We did not see the need for a graphic.*

3) Information relating to this question is scattered through document, but there was no concise definition or description of optimal woundfin or Virgin chub habitat. Other than stressing importance of permanently-watered reaches and thermal tolerances, not much information presented. *Response – specific habitat requirement are summarized in the Recovery Plan. The purpose of this document is to determine if a change in listing status is needed. In that context, the emphasis on striving to keep all, or at least more, of the river wet seemed adequate (till the next 5-year review).*

4) No information was presented on fishes occurring in Virgin River drainage reservoirs. Almost all attention on nonnative fishes was given to red shiner. Perhaps it is the only one that is a problem, but others documented in area. Need to at least explain or state that others not deemed an issue. *Response – We agree the emphasis on red shiner is disproportionate, but seems to reflect the state of our knowledge on threats. We did reference other species on page 29, and as stated at that point in the text red shiner control actions should address these species as well.*

5) Much of document depended upon monitoring data to assess trends and status. Although presentation of more specific information would have been helpful, there is no reason to doubt that both species have declined over past 30 years, despite almost Herculean efforts to conserve each. *Response – agreed.*

6) Document evidently references or cites all relevant reports that have been generated from work on woundfin and Virgin chub in Virgin River, but no published literature that might support or augment information referenced in document. For example, there is a large body of literature on changes in desert fish assemblages, natural and unnatural disturbance, and various means or approaches to reverse declining trends, but none of that is referenced in this document. Putting trend of Virgin River fishes in context of those in other arid-land systems would be helpful. *Response – good point; see above.*

The following comments refer to numbered comments or suggestions indicated on the 5-Year Status Review. In addition to these, a few comments / suggestions were made directly on the 5-Year Status Review. *We generally incorporated all editorial comments provided by this reviewer many of which are not transcribed below. Bracketed text was added to the reviewer's comment to clarify context.*

1) What does this mean? What are "other limiting physical factors?" Do you mean that adding Red shiner to an already stressed system (a consequence of human-induced modifications) is more than woundfin pops can withstand? The synergistic part is stillunclear. *Response – Yes, the point was that the successful red shiner invasion is a by-product of the habitat alteration. Upon further review, the 'synergistic' sentence was unnecessary – deleted.*

2) Just because chub persists where woundfin is declining does not mean chub is more tolerant of modified conditions. Following statement qualifies somewhat, but it remains dicey to suggest persistence is consequence of tolerance to modified habitat. *Response – We tried to qualify this statement by recognizing that these are very different animals, but the long term trend information suggests that chub populations have remained relatively stable in the upper river (red shiner absent) where woundfin populations have crashed.*

3) Seems you have some evidence that chub not tolerant of red shiner. *Response – the lower river chub population is located where flows are relatively stable (supported by the Littlefield springs) and yet available information suggest the population density is 0.1 that of the upper river population.*

4) Every reported use of this dataset is over 10 years old! But, earlier in this review, a statement made that considerable new information and insights since 1995. *Response - In the next paragraph, a more recent analysis (Holden et al. 2001) is referenced, which served as the platform for the incorporation of data through 2006.*

5) Population estimates are subject to same biases as catch indices. *Response – We agree to a point, but typically closed population, mark / recapture estimators are more dependent on capture probability than catchability.*

6) Define 'seine unit.' *Response – added text.*

7) Need to be a bit more careful with word choice and style—narrative is drifting into editorial and opinion rather than neutral presentation of information. *Response – the intention with 'most comprehensive' was only to reference the breadth of their analysis. No one prior to that study had considered that many years of data.*

8) No doubt each of these [degree of water development; effects of drought; effects of Quail Creek Dam failure; negative interactions with nonnative speices; effects of periodic red shiner removal efforts; periodic release of hatchery reared fish; and the high flows of 2005] is a stressor, but how were they quantified? Were specific analytical approaches used to assess impact of stressor? *Response – additional text added.*

9) Should specify when sampling began, what season, etc. You need to be sure reader knows specifically what dataset is. *Response – good comment, 'autumn' refers to August 15 – November 15 – language added.*

10) What kind of mark? Any recaps? *Response – text revised to address both questions.*

11) Perhaps all [Recovery program actions] converged to yield positive response, but this is largely conjecture. *Response – We agree, thus, we tried not to overstate this possible explanation.*

12) With no data, this is hearsay. A simple graph depicting woundfin density or abundance each year would be very helpful. *Response – graph added.*

13) Is size the determining factor for maturity? With genetic study results, appears Fridell & Morvilius incorrect. *Response – Good observation; or the small percentage of hatchery fish that were large enough spawned and that contribution was enough to detect in the genetic study. Data not sufficient to be more conclusive at this point in time.*

14) Is 'core area' [reference to chub population centers] just where numbers high or are these areas that provide essential elements for viable population? *Response – yes on the first count; presumably on the second.*

15) Am having some difficulty appreciated relevance of much of this to status review. The point is a population estimate (and 95% confidence interval pretty good), not whether this is best monitoring approach. Need to focus. *Response – Good point; we deleted text that speaks to monitoring approach.*

16) Are there hydrographs available? Presumably this is a negative relationship. *Response – Yes, a negative relationship was existent through 1999 (see Holden et al. 2001), I did not have time to update that analysis for this review.*

17) Was there among sites evaluation of trends? *Response – Hopefully, the addition of the trend graphics facilitate the related discussion throughout the text.*

18) Are you simply stating native fishes captured and held off-site during rotenone treatments? *Response – Yes, and although the "safe house" concept is simple, it does have implication to subsequent trend sampling.*

19) Did this analysis [link of woundfin densities at one location as a function of upstream densities] control for other variables that might affect abundance? *Response – Yes, but our thought was that the results of Holden et al. 2001 have been discussed so thoroughly by this point in the document that this was implied. However, we sympathize with the reviewer in that the format of the 5-year review does not lend itself to the most logical presentation of data.*

20) Rather muddled. Is this all species [reference to the concluding remarks at the end of each monitoring site section], or just chub and woundfin? Management actions have desired outcomes but they have not been manifested so do they belong in a status review? *Response – The final paragraph in each site section was intended to serve as a summary and in this case, the discussion captures both species (will add clarification). One could argue that the management actions should only be discussed under the threats section, but we think it is pertinent here as well.*

21) So did these flows [flood flows in 2005; particularly in the lower river] have detrimental affect on red shiner? *Response – discussed on the next page.*

22) And what is relevance of this information [discussion was trying to characterize that perhaps there is such a thing as too much flow]? *Response –The point being that whereas we saw the positive native fish response up river, i.e., more flow = good, the magnitude of the flood in the lower river crossed some threshold.*

23) Much of this is review of what has been done and not a status review. While it is good to provide overview of effort, you need a final statement re[garding] current status. *Response – We agree, that this review of stocking efforts only marginally fits the purpose of this document, but we would like to keep it here. As with the other monitoring site sections, the status information is summarized on the next page.*

24) What are 'typical' and 'normal' levels [in reference to historical measures of abundance of woundfin and chub]? Without some specifics, it is really hard to 'assess' status. *Response – Hopefully the inclusion of the trend graphs will assist here.*

25) Relation of these activities to status review is not clear. *Response – The status of the lower river populations (WF and VRC) are in much worse shape than the upper river. It was important to me to call out the need for a coordinated recovery effort in the lower river in conjunction with their dismal population status.*

26) The key question is whether Dexter fish have full range of diversity as wild, and what are protocols to ensure maintenance of diversity. *Response – We think the first question was answered. We will add something to the effect that the answer to the first question resulted from a successful genetics management plan. NOTE – unfortunately there was a catastrophic sequence of events in 2007 (drought, summer storms that may have carried toxic fire residue, sediment sluicing at the Quail Creek Diversion) that extirpated the wild population of woundfin. The hatchery stocks are all that is left.*

27) If available, data from thermographs would be helpful. *Response – We agree, that a picture would tell a better story. I tried to summarize pertinent information, but we were instructed to rely on available information. A summary graphic was not readily available.*

28) Does this mean no woundfin entrained? If fish entrained, its immaterial if diversion within critical habitat. *Response – will clarify that it also is located upstream of occupied habitat – good catch.*

29) Okay, it reduces threat, but has sediment been sluiced [reference to management at Qauil Creek Diversion Dam] per plan? If so, what was effect on fish? *Response – too early to tell.*

30) References needed. Also, flycatchers will nest in salt cedar as readily as willows—structure is key not plant species. *Response – In conversation with Greg Beatty, USFWS - SWWF lead, nesting and / or nesting success is affected, particularly in monoculture stands of tamarisk. Revised the language, accordingly.*

31) This contradicts preceding. *Response – Comments provided by USFWS-Las Vegas personnel added to clarify.*

32) What does 'resetting riparian ecosystem in places' mean? *Response – deleted reference to the riparian ecosystem – just referenced that large stands of tamarisk were removed during the 2005 flood. We focused on the need to take advantage of this natural removal.*

33) Is this really appropriate in 5-Year Status Review? Understand such activities [e.g., proposed Lake Powell pipeline] will have impact, but still seems out of place. Some statements border on 'pre-decisional.' Last sentence accepts development will happen, regardless. Is that correct? *Response – The Recovery Team wanted some recognition of the potential to benefit the river ecosystem with this unconventional tool.*

34) Has red shiner predation on woundfin or chub been documented. Are there other nonnatives? *Response – Not certain if it has been documented, but based on Rupert et al. 1993 (added) not much of an assumption.*

35) Again, would be helpful to list all nonnatives. Interesting that Mead is source of red shiner, given that red shiner is almost an obligate stream fish. Is red shiner regularly collected in Mead? Is there a reference that could be cited? *Response – other species addressed later in the text – sorry it came so late. Trying to characterize the red shiner dynamics in Lake Mead are considered beyond the scope of this review.*

36) How [the author's assumption that nonnative species other than red shiner do not present an immediate threat / concern]? *Response – These other species have been collected in the upper river, but never in densities that would suggest a significant threat – not to say that things won't change.*

37) Was blue tilapia removed or does it remain [throughout the Muddy River drainage in Nevada]? Should provide a little more information on other nonnatives. *Response - blue tilapia remain but have been reduced. Information provided by USFWS-Las Vegas personnel added to clarify – many thanks!*

38) What about baitfish regulations? What are sport fish management activities in reservoirs—are they source of nonnative fishes? *Response - We searched the fishing regulations for Nevada and Utah, and other than 'no live bait' in the drainage we did not see any other prevention or control language. We tried to address this in the Analysis of Threats section.*

39) Thought this category was more a catch-all of factors that negatively affect (other threats) listed organism, not a list of pro-resource management actions. *Response - In retrospect we agree with the reviewer. These sections were modified extensively.*

40) Seem rather limited [reference to Recommendations]. What about evaluation of bank revetments? Are reservoirs source of nonnatives? Implement adherence to zoning, etc. *With the assistance of USFWS-Las Vegas personnel the recommendations were revised and expanded.*

Dr. Paul B. Holden's comments, which respond directly to the six questions we asked in our peer review cover letter (received in letter format at the USFWS, Utah Field Office on August 6, 2007):

1) **Is our description and analysis of the biology, habitat, population trends, historic and current distribution of the species accurate?**
I think the report does a good job of summarizing the available information on these factors. I have the following specific comments. p. 2, 1.3.5, I was surprised that at the start of the 5-year review the Virgin River chub was listed as 2c versus 1 for the woundfin. The history to date suggests the woundfin does not have a high potential for recovery but that the chub likely does. The chub was listed in part due to little

information on its status. Work noted in the report has shown more chubs than perhaps some thought, once the proper sampling was completed. *We agree that a change in the Recovery Priority Number for woundfin is warranted. We have recommended that the Recovery Priority Number for the woundfin be changed to '1C.' Due to their biology woundfin have the potential to respond quickly to favorable environmental conditions, which conversely diminishes their ability to persist long term. The woundfin's potential for recovery should be closely considered in that reprioritization process.*

Page 4, 2.2.3 - This section notes the poor status of woundfin, but does not note similar characteristics for the chub. We now know more about the chub populations and that they are larger than perhaps thought, so this could be noted in this section. *Additional text added to clarify.*

Page. 15, paragraph 2, last sentence - It is my impression that stocked fish as well as wild fish contributed to the strong reproduction. VIf that is correct, this sentence could note that. *Noted in the discussion of genetics.*

Page 16 and top of p. 17 -This section discusses the section above Washington Fields, 6 to 7 miles of the best remaining habitat. I believe that it has been noted in various reports that the number of Virgin spinedace has increased in this section since Quail Creek inflow began. This is a strong indication that some changes have occurred to this section that may not be readily apparent, and that spinedace may now be favored over woundfin. These two species typically only overlap relatively small portions of their range. *The changes to Virgin River physical habitat downstream of Quail Creek Reservoir were clearly recognized and fully discussed.*

2) **Does our document provide accurate and adequate review and analysis of the factors affecting the species?**
Overall, you have noted the major points. Again, emphasis on some that are the major issues such as changes in flow could be added:

Entire report and p. 23 - The report notes some of the changes that occurred in woundfin population size but I think it could be enhanced in several areas. The big point that seems to be missing is that in the 1970s and early 1980s; over a million woundfin lived in the Virgin River. We now have a thousand or less, depending, on the year. All portions of the river have been impacted up to Pah Tempe. The big change in the habitat we now are looking at happened from the mid-1980s to the present, not early in the 20th Century. We *decided to let the measures of abundance (fish per seine unit) speak to the population changes over time. We have not seen a reference to a specific population estimate with reported confidence intervals for this species. I think we (the commenter and myself) make the same point.*

Page 23, 2.3.2.1 - I know it is very difficult to discuss issues related to Quail Creek and Sand Hollow, and these may be hardest to define. But Sand Hollow has had to change the water use in the upper river (last sentence, 1st paragraph in section). Also,

the flows below the Quail Creek outlet, the change in the fish fauna as noted above, the discrepancy in where the minimum flow of 86 cfs started, the efficiency of the Quail Creek diversion compared to the old diversions, and the apparent acceptance that 3-5 cfs is sufficient for native fish in a river with a natural baseflow of near 80 to 100 cfs, all question if adequate and accurate review and analysis of these factors have been taken into consideration. *We did not feel comfortable getting more specific than we did as to the effects on Virgin River hydrology from the Sand Hollow project. We respect this reviewer's perspective on the issue of 86 cfs and where it is delivered in the system and we both realize that a policy decision (which resulted in the formation of the Recovery Program) was made a long time ago. We think the discussion is clear as to the historical changes that have occurred in Virgin River hydrology at the current site of the Quail Creek Diversion. We do not judge the adequacy of 3 cfs below Quail Creek Diversion in terms of the historical hydrology. However, this reviewer must understand how difficult it is to restore any flow, that has been appropriated under State and Federal law, into rivers of the American Southwest.*

3) **Are our assumptions and definitions of suitable habitat logical and adequate?**
I am not sure where this information is in the document. It seems scattered but could be put into a section by itself. Is 3 cfs enough for the main Virgin below Quail Creek diversion, I think the info gathered said no, but your report suggest otherwise. Is 5 cfs enough below Washington Fields ? Any reasonable analysis would likely say no, except to keep fish drifting down from above alive for awhile, but the document seems to suggest it is. If 86 cfs was the best minimum flow that the FWS could come up with before Quail Creek, why isn't it good for the entire river? *Our response to the previous question serves as our position on these issues as well.*

4) **Are there any significant oversights, omissions or inconsistencies in our findings and 5-year review ?**
The points I raised above about p. 23, and under question 3 may be oversights or inconsistencies.

Page 30, 2.3.2.4 - The issues related to the 86 cfs and where does it start, as well as the construction of Sand Hollow with essentially no endangered species review, suggests existing regulations are not adequate. *This reviewer's comment is appropriate as it applies to the adequacy of existing regulatory mechanisms, but immediately puts us in the arena of policy issues. The peer reviewers were directed to review the relevance of the science used in our review. We have responded to the technical aspects of diminished flows issue above and re-crafted our Recommendations to recognize this reviewer's valid concern for habitat restoration.*

5) **Are our conclusions logical and supported by the evidence we provide?**
I am not sure just what conclusions you refer to. The conclusion that change (loss) of flow is a major issue seems to come out from your report. I agree with that. Other factors such as red shiner are also large impacts affecting certain areas and the report

notes that well also. *We have summarized the revised text in the Synthesis section to clearly recommend that no change in current listing status (endangered for both species) is warranted.*

On p. 26 you note that the completion of the Washington Fields fish screen and restoration of flow below the most successful accomplishment to date. At first I didn't know if I agreed with this, but what else has been done? Perhaps this is the real message of your report. With all the time and money that has been spent, nothing of real consequence has been done to benefit, the two endangered fish. They are worse off now than ever before, and the things that are being done are minor accomplishments, at best. The million or more woundfin I talked about earlier were there with out a fish screen, and there was flow below the diversion most years. *We understand this reviewer's frustration with the pace of recovery, but as with most endangered species the issues are monumentally complex. We disagree that nothing of real consequence has been done. Holding the line against the invasion of red shiner upstream of Washington Fields Diversion has been characterized (by another peer reviewer) as a "herculean" effort. The amount of time spent monitoring the populations to better understand threats has been huge. That information has put the behavioral thermal maximum and critical thermal maximum issue into a management context and may very well result in restoration of flow (via a back flow pipeline) in the very near future. Recovery will be that much more difficult in the lower river, but finally stakeholders are sitting at the table to develop and implement a coordinated effort.*

Perhaps the biggest issue with your review is what to do, what needs to be done, and-how to do it. I have always said that flow is the mayor issue for all reaches, especially the one above Washington Fields. Restoration of flows in that reach must be the number one recommended future action. Having a large population of woundfin and chub in that reach is extremely important for all downstream reaches. Having young drift down from a large population, as they did for many years, gives some hope to the lower reaches as red shiner eradication moves forward. And if red shiner eradication proves as difficult in the future as it has been in the past a thriving population in 20 miles of river will be extremely important. Therefore, flow restoration is the primary objective to accomplish as quickly as possible. Bringing Quail Creek 'water back up, or using Lake Powell pipeline water, or some other method needs to be the highest priority. *The text, and in particular the recommendations have been revised to address this reviewer's concern (probably not to his complete satisfaction).*

6) **Did we include all necessary and pertinent literature to support our assumptions and conclusions?**

I think most of the pertinent information is presented. As noted above issues related to the minimum flow (86 cfs) and attempts to move it up the river where it should be are not noted but politically I suspect you cannot include that. I appreciate the chance to review your document and hope my comments will help in preparation of the final review. I don't want to be negative and offer these comments in response to your

questions of adequacy. We need to guard against being satisfied with putting in the effort, and spending the money, when in the end they do not produce the desired result. *We appreciate this reviewer's recognition of sensitivity of some of the issues he has raised. We also appreciate his advocacy for the recovery of these species – it is important to be reminded of these strong opinions as we push ahead toward recovery.*

Dr. Keith Gido's comments, which respond directly to the six questions we asked in our peer review cover letter (received via electronic mail on August 20, 2007):

Overall, this is an impressive document that incorporates a wealth of knowledge on the long-term dynamics of these two fish species in the Virgin River. The patterns of decline in both habitat availability and population status are clear. There are a number of valid management recommendations suggested to maintain and recover these populations. In particular, establishing other populations (e.g., in the Gila River) seem like a critical step toward the recovery of these species.

1) **Is our description and analysis of the biology, habitat, population trends, historic and current distribution of the species accurate?**
   I have a limited knowledge of the population dynamics of Virgin River fishes, thus assume the information in the report accurately reflects the declining trends in these species. My only suggestion concerns the quantification of abundance. I appreciate the problems involved with making inferences on population trends with non-standardized effort. The use of the number of fish per seine unit may be the best approach. However, this is a non-standard unit of effort that makes comparisons across systems difficult. I wonder if it would be helpful to mention total numbers of individuals captured along with the effort (e.g., number of seine hauls). Or, perhaps provide some estimate of how large an area is sampled during one seine unit. We *included additional information as to what constituted a seine unit and a better description of the metric itself. We have not fully addressed this reviewer's comment and concern, but hope that my revisions provide readers with a clear understanding of the trends.*

2) **Does our document provide accurate and adequate review and analysis of the factors affecting the species?**
   The document does a nice job summarizing the factors that could potentially influence these fishes. I wonder if adding some more quantitative data might help increase the rigor of these statements. For example, there are a few statements suggesting "significant" positive or negative associations. Would it be appropriate to include correlation coefficients or probability values? In addition, there is a large emphasis on the negative effects of red shiners on these two native species. More information on the nature of those interactions would be helpful in justifying the emphasis placed on this management activity. Has there been any experimental work to show how these species interact? Is there data to show the recovery of natives when red shiners are removed? Are there documented cases of predation? Are food resources limiting in this system? I do not doubt red shiners have a negative effect on

these fishes, but there also might be concurrent factors that favor the spread of nonnatives and are detrimental to the natives. *As this reviewer suggests, with a standardized monitoring data set that spans 30+ consecutive years, there are opportunities for more rigorous data analyses. We were really at the mercy of an exceptionally dedicated UDWR employee, Mr. Michael Golden, who was experienced with the database and provided the data for the trend analysis included. We are sure this reviewer would agree that mining a dataset, which was partially gathered on a volunteer basis, can become extremely time consuming and more rigorous analyses may not be possible. Our charge was to use existing information to determine if a change in listing status was warranted. We think the analysis included in this 5-yr review was adequate to satisfy that objective and ultimately supports the USFWS recommendation. Regarding red shiner, we drew more heavily on the available literature that speaks to the negative interactions of red shiner and other nonnative cyprinids on native fish of the American Southwest.*

I also would like to have seen more detail on the success of the hatchery program. It was mentioned that stocked individuals had successfully recruited, but there was little quantitative information associated with that claim. I assume a fair amount of resources have gone into these programs. It would be nice to know how successful they have been relative to other management activities. *The subject discussion summarizes information available in agency reports. Understand that woundfin have only been stocked in what researchers would consider meaningful numbers for a few years. Stocking size, stocking rates, stocking locations, and environmental conditions have all varied throughout that short timeframe. We have cited the appropriate agency reports that delve into the issue more deeply, but again we felt that information presented in this review was appropriate for the task at hand.*

3) **Are our assumptions and definitions of suitable habitat logical and adequate?**
Yes.

4) **Are there any significant oversights, omissions or inconsistencies in our findings and 5-year review?**
I wonder if a section addressing gaps in our understanding the ecology of this system would be useful. The document provides some suggestions on management activities, but there seems to be some basic understanding of limiting factors that could be emphasized. Just to name a few: the importance of maintaining connectivity of the system in regard to the resilience of these fishes, population dynamics of adult Virgin River Chub, interactions with nonnative. *Good comment. We tried to address this concern throughout the body of the text. We considered adding a Research recommendation along these lines, but was not sure how to characterize it. The monitoring program continues to bolster the information base on limiting factors. Our sense is that most researchers and managers feel like there is enough information to warrant on the ground action (expand red shiner management and do whatever is possible to improve base flow conditions throughout Critical Habitat.*

5) **Are our conclusions logical and supported by the evidence we provide?**
For the most part, yes. As mentioned above, some more detail of patterns referenced in the text might be helpful. I'm not sure the limitation of this document, but can you include tables or figures? *A map and trend analyses figures were provided for each species and each monitoring site.*

6) **Did we include all necessary and pertinent literature to support our assumptions and conclusions?**
I did a quick search for literature on the Web of Science. There seems to be a lack of peer-reviewed literature on these species. I ran across a few papers that were not included in the literature. I'm pretty sure the authors of the 5-year review are aware of these papers, but thought I'd list them anyway, in case some are relevant. I also noted a lack of literature citations from similar systems in the Colorado River. Perhaps this literature could be used to substantiate the relevance of presumed stressors in this system. For example, red shiner are problematic throughout the Colorado River basin and several studies have evaluated their biology and impacts of other native fish species.

Vu NV, Keeler-Foster CL, Spies IB, et al. Twelve microsatellite markers developed in woundfin (Plagopterus argentissimus), an endangered warmwater **fish** of the lower Colorado **River** basin MOLECULAR ECOLOGY NOTES 5 (2): 302-304 JUN 2005

DEMARAIS BD, DOWLING TE, MINCKLEY WL POST-PERTURBATION GENETIC CHANGES IN POPULATIONS OF ENDANGERED **VIRGIN RIVER** CHUBS CONSERVATION BIOLOGY 7 (2): 334-341 JUN 1993

GREGER PD, DEACON JE DIEL FOOD UTILIZATION BY **WOUNDFIN**, PLAGOPTERUS-ARGENTISSIMUS, IN VIRGIN RIVER, ARIZONA ENVIRONMENTAL BIOLOGY OF FISHES 19 (1): 73-77 MAY 1987

DEACON JE THE ENDANGERED **WOUNDFIN** AND WATER MANAGEMENT IN THE VIRGIN RIVER, UTAH, ARIZONA, NEVADA FISHERIES 13 (1): 18-24 JAN-FEB 1988

The final draft has been revised significantly to address this reviewer's comment.

Dr. C.O. Minckley's comments, (received in letter format at the USFWS, Utah Field Office on August 3, 2007):

Dr. Minckley provided the following general comment (other editorial comments were incorporated in the final):

> I have read the document and feel that you have addressed the status of the woundfin and Virgin River chub well in this 5-year review. I wish you luck in achieving your goals for the next 5 years and maintaining these unique fishes.