

**Beautiful shiner**  
*(Cyprinella formosa)*

**5-Year Review:  
Summary and Evaluation**

**U.S. Fish and Wildlife Service  
San Bernardino National Wildlife Refuge  
Douglas, Arizona**

**5-YEAR REVIEW**  
**Beautiful shiner (*Cyprinella formosa*)**

**1.0 GENERAL INFORMATION**

**1.1 Reviewers:**

**Lead Regional or Headquarters Office:** Southwest Regional Office, Region 2  
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**Cooperating Field Office(s):** Arizona Ecological Services Office, Tucson, AZ; (520) 670-6144

**1.2 Methodology used to complete the review:**

This review was an effort made by San Bernardino National Wildlife Refuge (NWR) and the Division of Biological Sciences with cooperation from the Arizona Ecological Services Field Office. The *Yaqui Fishes Recovery Plan* (USFWS 1995) was used to describe the species' earlier status; annual monitoring data and literature review were used to conduct the status review and make a classification recommendation.

**1.3 Background:**

**1.3.1 FR Notice citation announcing initiation of this review:**

83 FR 25034 and 73 FR 14995

**1.3.2 Listing history**

Original Listing

**FR notice:** 49 FR 34490

**Date listed:** 31 August 1984

**Entity listed:** species

**Classification:** threatened

**1.3.3 Associated rulemakings:**

Critical habitat was designated in 49 FR 34490 as all aquatic habitats on San Bernardino National Wildlife Refuge.

**1.3.4 Review History:**

This is the first 5-year review for beautiful shiner.

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

2

**1.3.6 Recovery Plan or Outline**

**Name of plan or outline:** Yaqui Fishes Recovery Plan.

**Date issued:** 29 March 1995

**Dates of previous revisions, if applicable:** N/A

**2.0 REVIEW ANALYSIS**

**2.1 Application of the 1996 Distinct Population Segment (DPS) policy**

**2.1.1 Is the species under review a vertebrate?**

Yes  
 No

**2.1.2 Is the species under review listed as a DPS?**

Yes  
 No

**2.1.3 Is there relevant new information for this species regarding the application of the DPS policy?**

Yes  
 No

**2.2 Recovery Criteria**

**2.2.1 Does the species have a final, approved recovery plan?**

Yes  
 No

**2.2.1.1 Does the recovery plan contain objective, measurable criteria?**

Yes  
 No

**2.2.2 Recovery Related Information.**

**2.2.2.1 Is the most up-to date information on the biology of the species and its habitat considered in the current recovery criteria?**

Yes  
  X   *No, new information is discussed below*

**2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:**

General recovery criteria for all Rio Yaqui species, below, were identified with the limited information available at that time:

- a) Secure and protect San Bernardino Valley aquifers so that all artesian well and other flows from subsurface sources are perennial. Secure and protect Leslie Creek, Black Draw, AZ, and Mimbres River, NM, watersheds to ensure adequate, perennial flow. And,
- b) Eradicate all non-indigenous fish species and other undesirable organisms such as bullfrogs from critical habitat. And,
- c) Protect critical habitat and other habitats where species of concern occur or are reestablished from human disturbances including excessive grazing, irrigated agriculture, mining, introductions of non-indigenous species, and water diversion or removal.

In addition to the general recovery points a-c, above, beautiful shiner delisting will occur when:

- 1) Arizona populations of Yaqui beautiful shiner are reestablished, self-sustaining, and secure for at least 10 years in all suitable, existing, and reclaimed San Bernardino NWR and Leslie Canyon NWR habitats;
- 2) Guzman beautiful shiner is reestablished, self-sustaining, and secure for at least 10 years in the Mimbres River and other available habitats within its historic range in NM; and
- 3) Self-sustaining populations of both forms are secure within their historical ranges in Mexico.

The general criteria have been met in part. Portions of the San Bernardino aquifer are protected by conservation easements and further easements are being pursued; the entire Leslie Creek drainage is protected by a conservation easement held by the US Fish and Wildlife Service; but little of the Mimbres Basin is protected. All non-indigenous fish species have been eradicated from critical habitat at San Bernardino NWR, but bullfrogs persist though posing little risk to beautiful shiner. Human disturbance is minimized in all critical habitat by restricted access to San Bernardino NWR, and there are no present or anticipated disturbances such as those listed in the criteria.

Criteria specific to beautiful shiner have not been met: self-sustaining populations are present at San Bernardino NWR, and are not currently present at Leslie Canyon NWR, where low natural densities make regular monitoring difficult. There are no known populations of Guzman beautiful shiner in the Mimbres River. There is no current information on the status of beautiful shiner in Mexico, but continued water development and habitat destruction in the Yaqui basin suggest that the species is not secure in their native range.

## 2.3 Updated Information and Current Species Status

### 2.3.1 Biology and Habitat:

Beautiful shiner (*Cyprinella formosa*) is a small cyprinid fish native to Rio Yaqui of southeastern Arizona, the Rio Mimbres of southwestern New Mexico, USA, and the Rio Yaqui of northwestern Chihuahua and northeastern Sonora, Mexico (49 FR 34490). Minckley (1973) disputed the New Mexico reference because of lack of specimens. Males are blue-bodied and possess orange fins during the breeding season; females and off-season males are silvery and relatively non-descript. Vives (1993) suggested that egg deposition occurs over small gravel and in crevices. This is likely similar to red shiner (*Cyprinella lutrensis*) spawning, which show a preference for spawning on red substrates and in two to three millimeter (mm) wide crevices (Gale 1986, Radke 2001) At San Bernardino NWR, captive beautiful shiner have been observed to lay eggs on submerged structures such as gravel substrates and artificial plants, and likely use live vegetation and dead woody structure in refuge wetlands (Radke, pers. com).

Beautiful shiner is known to occupy small and medium-sized streams and open lentic habitats (Minckley 1973, Miller et al. 2005). Very little information exists on the autecology and community ecology of the species; in the United States, beautiful shiner population densities appear to naturally be low and captures or observations are rare.

#### 2.3.1.1 New information on the species' biology and life history:

Maes (1995) studied the ecology of Yaqui topminnow and Yaqui chub, but also made observations of beautiful shiner. His 22 observations indicated that beautiful shiner systematically use the upper water column, but do not have preferences of cover or substrate type. The species often appears rare and does not inhabit all wetlands (about 12 of 35 wetlands) near and around San Bernardino NWR and Leslie Canyon NWR. For example, from 2007 to 2012 Refuge staff only captured 632 beautiful shiner. Except for a single year between 2007 and 2012, Refuge staff typically captured fewer than 99 individuals total annually, suggesting that when this species is present it either naturally occurs at low densities or exhibits behaviors that do not favor capture using standard minnow traps.

Stewart et al. (2017) quantified site-specific correlates of detection and abundance of beautiful shiner in wetlands. Estimates of detection probability and total 'local' abundance (sum of the site-specific bias-corrected estimates of abundance at a site) ranged from 0.06 to 0.25 and 4 to 1019 for beautiful shiner. Detectability increased while abundance decreased with increasing water temperatures (Figure 1). Meanwhile, abundance fell by 70% over this same temperature span (Figure 2). Vegetation negatively influenced detectability of beautiful shiner, and as a percent vegetation rose, the abundance of beautiful shiner also declined. At 10% submergent aquatic vegetation, beautiful shiner abundance was 145 (95% CI = 60, 240) and at 80%

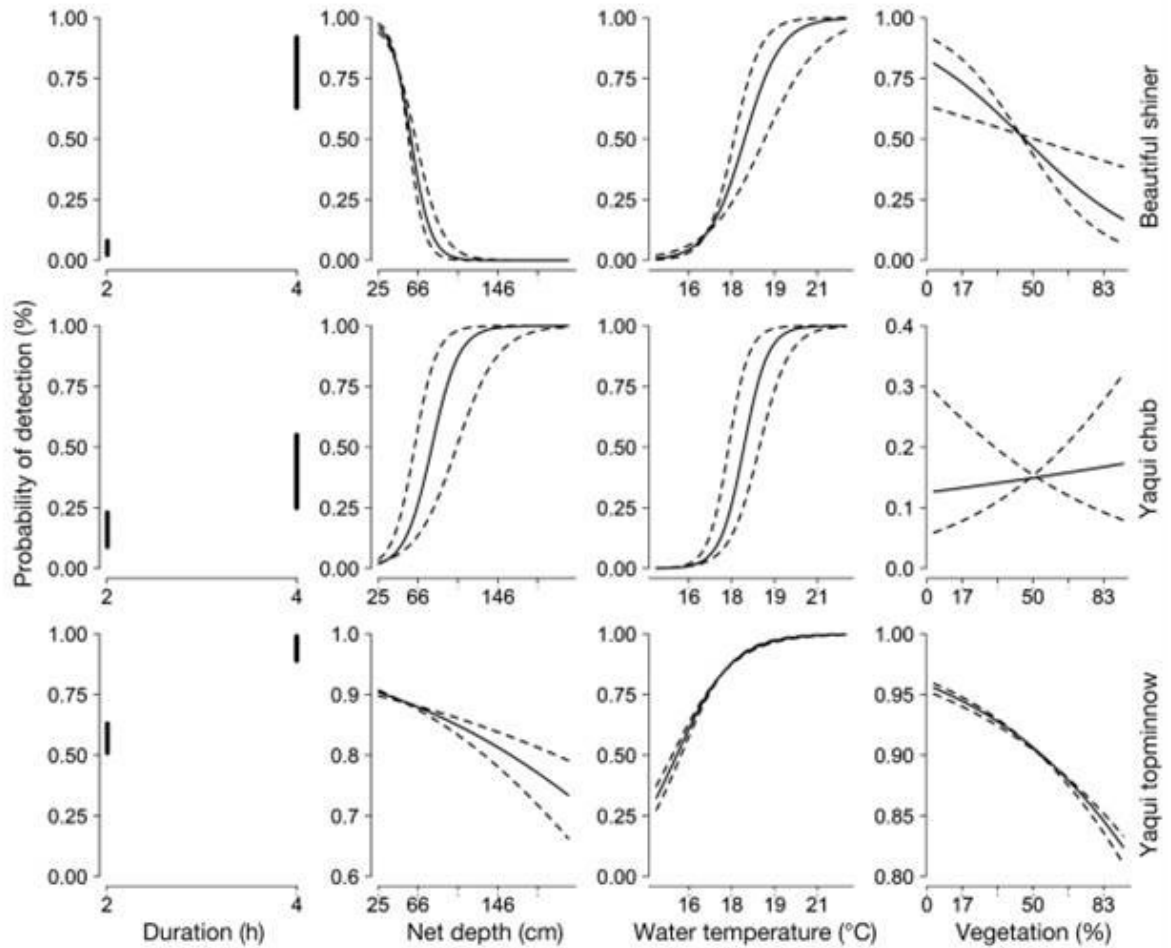
vegetation, abundance was 50 (95% CI = 45, 55). As net depth increased, detectability for beautiful shiner declined but abundance increased. For example, estimated detection probabilities for beautiful shiner at 25 cm were 98% (95% CI = 97, 100), while abundance was essentially 0 (Figures 1 and 2). Meanwhile, estimated detectability at 500 cm was 1% (95% CI = 0, 2) and mean abundance 100 (95% CI = 25, 300).

The interactions between invasive Asian tapeworm (*Bothriocephalus acheilognathus*) and beautiful shiner are unknown, though Kline (2007) reported that Yaqui chub infected with Asian tapeworm experienced considerably lower growth rates than those not exposed. The population-level effects of reduced growth rates are unknown, and field observations show no pattern.

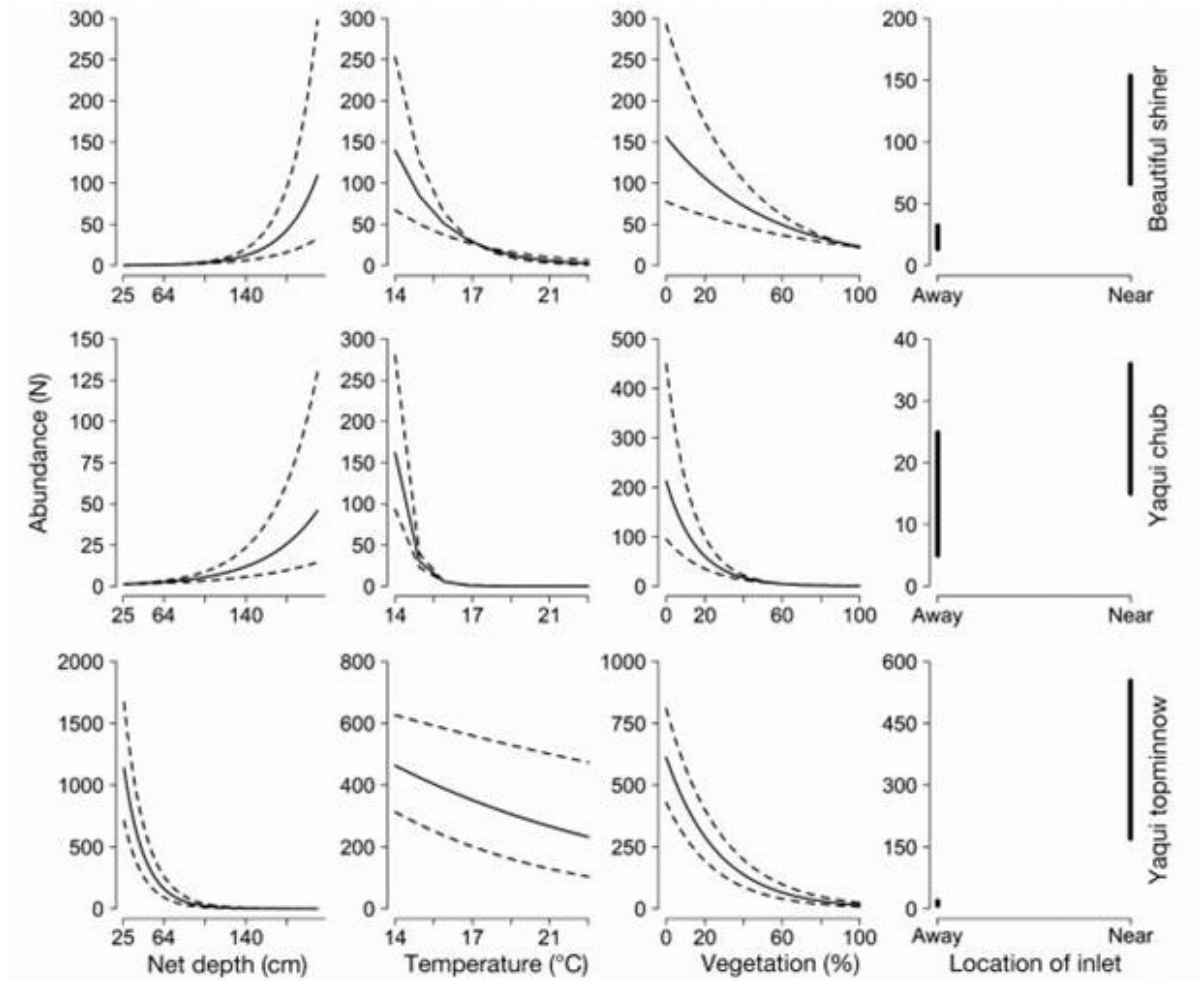
It is suspected the spawning behavior of beautiful shiner is similar to the of the red shiner *Cyprinella lutrensis* (Gale 1986, Radke 2001). At San Bernardino NWR, reproduction appears to occur principally during May – July in warmer temperatures and long day lengths. Captive fish from San Bernardino NWR laid eggs that adhered to artificial aquarium plants, and females were also observed laying eggs in gravel substrates. It is expected that they do the same on woody debris and aquatic vegetation in refuge ponds. In captivity, juveniles hatched and sought the cover of artificial aquarium plants, and newly hatched shiner that strayed into deeper water away from cover were quickly eaten by adults in aquaria. Using light traps, hundreds of fry have been captured in one night following hatching and successfully raised in aquaria absent of adult fish. These “captive raised” shiner have previously been used to stock refuge ponds and to provide permitted institutions with display fish (Radke, pers. com.).

However, little is known about how their reproductive biology translates to recruitment of juveniles given the observed number of adults. Young and Stewart (In preparation) used historical data to develop stock-recruitment models to describe the relationship between abundance of adults (spawners) and juveniles (recruits) to get an idea of the recruitment relationship in a wild setting (Figure 3), such as the spring-fed ponds at San Bernardino NWR. The model-based exercise found that at the higher population sizes (though low), density-dependent processes potentially reduced the number of recruits produced per spawner, likely as a result from competition for habitats and food or even predation on young by adults or other species, which leads to limits on population sizes in the wild and results in less than proportional increases in recruitment with population size. Overall, the best-overall model from Young and Stewart (In preparation) predicted that 10 adults per trap produced 5 juveniles per trap on average (Figure 3). Given this relationship, the populations replace less than half the number of adults per year in an established population. However, translocations are being used to prevent population collapse by supplementing low recruitment of existing populations

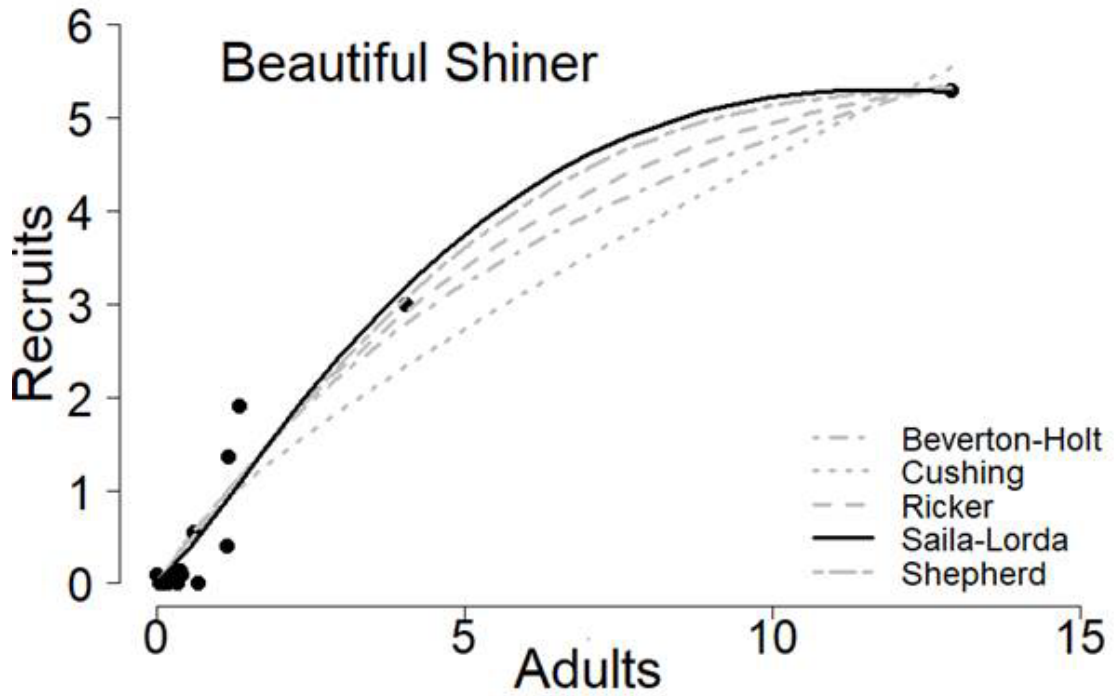
and to establish new populations to ensure the perpetuity at the Refuge.



**Figure 1.** Estimated mean conditional detection probabilities ( $p|N$ ) in relation to soak duration (2 vs. 4 h), trap depth (cm), water temperature (C), and submergent aquatic vegetation (%) for beautiful shiner *Cyprinella formosa*, Yaqui chub *Gila purpurea*, and Yaqui topminnow *Poeciliopsis occidentalis sonoriensis*. Middle lines: posterior means; dashed lines: 95% credible intervals.



**Figure 2.** Estimated mean site-specific abundance estimates,  $f(N|\Lambda\varepsilon)$ , in relation to trap depth (cm), water temperature (C), submergent aquatic vegetation (%), and location of nets relative to the inlet of the sampled wetlands for beautiful shiner *Cyprinella formosa*, Yaqui chub *Gila purpurea*, and Yaqui topminnow *Poeciliopsis occidentalis sonoriensis*. Middle lines: posterior means; dashed lines: 95% credible intervals.



**Figure 3.** Graphic representation between the numbers of age 0 beautiful shiner *Cyprinella formosa* per trap net versus the number of adults per trap net (typically 20 traps are used to survey each pond). Predicted values for the Beverton-Holt, Cushing, Ricker, Saila-Lorda, and Shepherd stock-recruit models are shown. Black line indicates the best-overall model from the candidate set.

**2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:**

Virtually no data exist as to absolute population trends. Beautiful shiners were found in two wetlands at San Bernardino NWR in 2006, and have now been reestablished in about 12 wetlands as of 2019. Hendrickson et al. (1981) surveyed the Rio Yaqui (Mexico and the United States) and tributaries in the late 1970s and early 1980s, finding beautiful shiner relatively widespread but locally uncommon in the upper reaches of the river system. No studies before or since the Recovery Plan (1995) have investigated the demography of beautiful shiner.

**2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):**

Since the species listing in 1984, several studies have investigated *Cyprinella* systematics (e.g., Mayden 1989, Gold et al. 1992, Simons and Mayden 1999, Broughton and Gold 2000, Schonhuth et al. 2008). An outstanding question that has not been fully addressed in these studies, however, is a determination of the distinction between beautiful shiner (*Cyprinella formosa mearnsi*) and Guzman beautiful shiner (*C. formosa formosa*): the two populations are separated by the North American Continental Divide. Broughton and Gold (2000) used ND2 and ND4L genes from numerous *Cyprinella*, but did not use *C. formosa* samples from both the Rio Yaqui and the Guzman Basin. Schonhuth et al. (2008) used four genes but both beautiful shiner samples came from the Guzman basin. However, Wood and Mayden (2002) used allozyme data to examine speciation within the beautiful shiner group and found considerable allozyme variation between drainages, including a consistent placement of *Cyprinella bocagrande* between lineages of beautiful shiner (i.e., making *C. formosa* polyphyletic). Recent reports from Wade Wilson (USFWS unpublished report) show that the relationship between the two is complex, and that current mitochondrial and microsatellite results show that the Guzman beautiful shiner and the Yaqui beautiful shiner are genetically divergent and should be considered distinct subspecies. In summary, future genetic management plans need to finalize judgement and determine if conservation needs be addressed separately for the Guzman beautiful shiner and the Yaqui beautiful shiner.

**2.3.1.4 Taxonomic classification or changes in nomenclature:**

The nomenclature of beautiful shiner has changed numerous times since the species' description in 1857, but recent evidence suggests that the Guzman beautiful shiner and Yaqui beautiful shiner are genetically

divergent and should be considered distinct subspecies (W. Wilson [USFWS] unpublished report). However, official changes to their classification and nomenclature need to be further explored and validated.

**2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):**

Habitat alterations extirpated the beautiful shiner from the US in 1970, and the species continues to suffer reductions in Mexico as a result of land use changes and the introduction of non-native species such as red shiner (USFWS 1995).

About 900 Yaqui beautiful shiner were collected under permit in Chihuahua from Arroyo Moctezuma on the Bavispe drainage during October 1989. These fish were held and propagated at Dexter National Fish Hatchery and 300 fish were ultimately reintroduced into Twin Pond on San Bernardino NWR on May 15, 1990. All remaining fish in Arizona come from this original stocking. In addition, the Service has about 5,000 beautiful shiners of the Guzman lineage currently at Dexter National Fish Hatchery. These individuals are the result of 16 individuals collected from the Rio Piedras Verde, a tributary of the Rio Casas Grande, Chihuahua, Mexico in 1978 (Radke, pers. com.).

The Yaqui Fishes Recovery Plan (USFWS 1995) states that beautiful shiner were reestablished in three wetlands at San Bernardino NWR in 1990, and as of 2019, the shiner is believed to occupy about 12 sites in the United States. The Arizona-Sonora Desert Museum is holding and breeding beautiful shiner provided from San Bernardino NWR for display purposes, and San Bernardino NWR stock are also held for display at the National Aquarium in Washington D.C. (Radke, pers. com.).

Abarca et al. (1995) reported on sampling from the Rio Bavispe in the tres rios area (i.e., the convergence of rios Gavilan, Negro, and La Cueva), where they found beautiful shiner in 9 of 12 sampled sites. There have been no watershed-scale survey of the Rio Yaqui since the work of Hendrickson et al. (1981); new data are needed.

The present range of Yaqui beautiful shiner expanded in 2008 with the implementation of a Safe Harbor Agreement with owners of the Bar Boot Ranch, upstream from Leslie Canyon NWR. The agreement permitted reestablishment of beautiful shiner populations in two wetlands across this 25,000-acre area.

**2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):**

Habitat conditions in the U.S. have likely stabilized for the Yaqui beautiful shiner. Wetland habitats have been restored and expanded,

watershed integrity has been maintained, and conservation easements are being pursued in the region. Habitat for the Guzman beautiful shiner is not protected in the Mimbres River. However, objective and quantitative analysis of the habitat status in Mexico is needed.

#### **2.3.1.7 Other:**

Currently, the construction of 25 miles of border security infra-structure (30-foot tall pedestrian barrier supported by a 10-foot deep concrete footing) across the San Bernardino Valley between the United States and Mexico identifies the need to utilize 700,000 gallons of water each day of construction (Department of Homeland Security and Environmental Protection Agency, email communication August 8, 2019). This equated to over 4,000,000 gallons of water in the month of December 2019. If the identified volume of water is withdrawn from the San Bernardino Valley groundwater aquifer, negative influences to the artesian flows that support all San Bernardino NWR wetlands are anticipated, and the future status of Yaqui chub potentially jeopardized. The construction period has been extended several months into 2021. We have a better idea what true volume of water is being used daily/weekly/monthly and it is less than 700,000 per day. Two refuge wells now have zero artesian flow, all others are experiencing decreasing flow. The average gallons per day or per month continue to change, so exact mathematics remains incapable of supporting a precise model of impacts to the aquifer, but the 2003 FWS Pump Test results are holding true.

### **2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)**

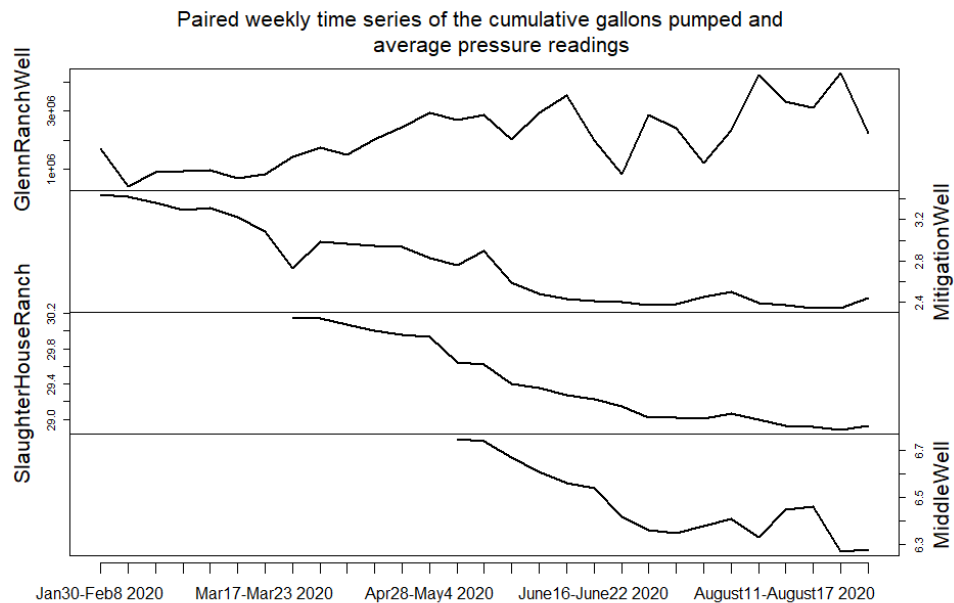
#### **2.3.2.1 Present or threatened destruction, modification, or curtailment of its habitat or range:**

The listing package for beautiful shiner (49 FR 34490) enumerated habitat destruction and modification as the greatest threats to the species' continued existence. In fact, in 2020 following construction of 25 miles of border security infrastructure in the San Bernardino Valley, which includes the anticipated withdrawal of over 700,000 gallons of water per day to support concrete production during the construction period (Department of Homeland Security and Environmental Protection Agency, email communication August 8, 2019). From November 2019 through September 2020, the amount pumping has significantly increased through time. These data, along with mean pressure readings from Mitigation Well and Middle Well on San Bernardino NWR, as well as those readings from Slaughter House Ranch (a conservation easement near San Bernardino NWR), are represented in the Table 1.

**Table 1.** Cumulative gallons of water removed per week from Glenn Ranch Well and associated weekly pressure ( $\psi$ ) readings at Mitigation Well, Slaughter House Ranch and Middle Well from November 2019 to September 2020.

Period	Glenn Ranch Well (cumulative gallons per week)	Mitigation Well (average $\psi$ per week)	Slaughter House Ranch (average $\psi$ per week)	Middle Well (average $\psi$ per week)
November 2019	2731400	3.54		
December 2019	1510900	3.64		
January 1 – 29 2020	1805700	3.63		
January 30 – February 8 2020	1713500	3.44		
February 9 – 14 2020	427400	3.42		
February 15 – 21 2020	901400	3.36		
February 22 – 28 2020	NA (944000)	3.29		
February 29 – March 3 2020	986600	3.31		
March 4 – 16 2020	705000	3.22		
March 17 – 23 2020	844000	3.09		
March 24 – 30 2020	1430400	2.73	30.16	
March 31 – April 6 2020	1746200	2.99	30.14	
April 7 – 14 2020	1506100	2.97	30.07	
April 15 – 20 2020	2026400	2.95	30.01	
April 21 – 27 2020	2444300	2.94	29.96	
April 28 – May 4 2020	2946100	2.83	29.94	
May 5 – 12 2020	2710700	2.76	29.64	6.75
May 13 – 18 2020	2857400	2.90	29.62	6.74
May 19 – June 1 2020	2044500	2.59	29.40	6.67
June 2 – June 8 2020	2940200	2.48	29.35	6.61
June 9 – June 15 2020	3543300	2.43	29.27	6.56
June 16 – June 22 2020	1993100	2.41	29.23	6.54
June 23 – July 6 2020	820900	2.40	29.15	6.42
July 7 – July 13 2020	2875300	2.37	29.02	6.36
July 14 – July 20 2020	2403200	2.38	29.02	6.35
July 21 – July 27 2020	1207000	2.45	29.01	6.38
July 28 – August 3 2020	2358600	2.59	29.06	6.41
August 4 – August 10 2020	4227300	2.39	28.99	6.33
August 11 – August 17 2020	3327700	2.37	28.93	6.45
August 18 – August 24 2020	3127000	2.34	28.91	6.46
August 25 – August 30 2020	4298600	2.34	28.88	6.27
August 31 – September 9 2020	2248000	2.44	28.92	6.28

The wetland ponds that have long supported beautiful shiner populations are going dry because of reduced artesian flow. Recently the USFWS developed a time series using data from the border security well (Glenn Ranch Well) located two miles from San Bernardino NWR and two wells located on the Refuge (Mitigation Well) and one on a conservation easement [Slaughter House Ranch] located near the refuge to determine how on-the-ground effects due to pumping for infra-structure are impacting the Refuge wells. This allows us to determine if there is a direct statistical link with the border security infrastructure project and the loss in artesian flow resulting in ponds drying. We found that as the gallons produced per time period increases over time at the border security well, then the average pressure readings at Mitigation Well (located at San Bernardino NWR), Middle Well (located at San Bernardino NWR), and Slaughter House Ranch Well decline significantly.

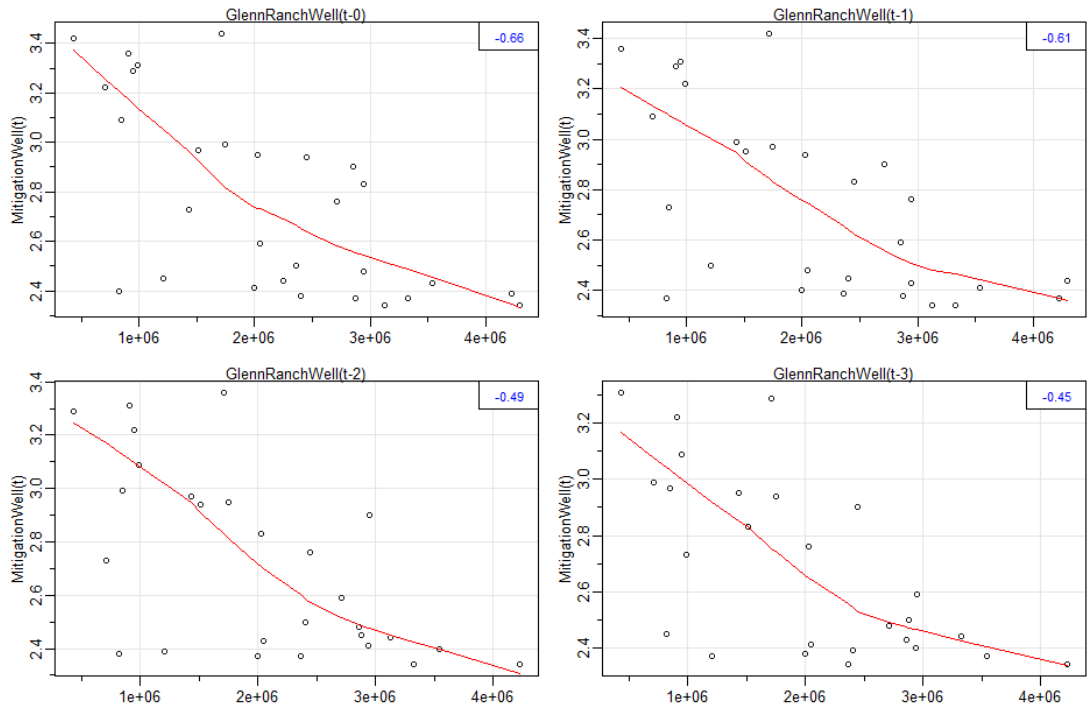


**Figure 4:** Time series of cumulative gallons per period from Glenn Ranch Well (top) and average pressure readings from Mitigation Well (located at San Bernardino NWR (2<sup>nd</sup> row)), Slaughter House Ranch Well (conservation easement located near San Bernardino NWR (3<sup>rd</sup> row)), and Middle Well (located at San Bernardino NWR (4<sup>th</sup> row)) from November 2019 to September 2020.

Figure 4 shows that as the weekly gallons produced increases over time at Glenn Ranch Well, the average weekly pressure readings at Mitigation Well declines significantly. Additionally, negative declines at both Slaughter House Ranch Well and Middle Well are also present. Next, we used a statistical method (i.e., cross correlation analysis) that tracks the movements between Glenn Ranch Well and

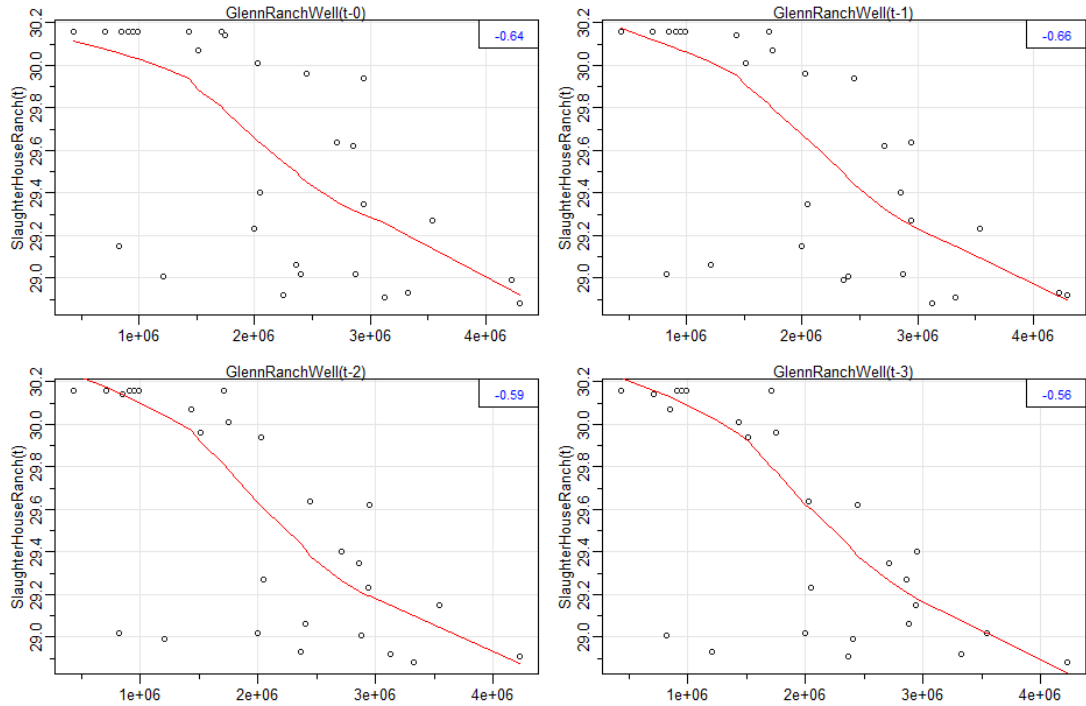
those located in-and-around the Refuge to determine if the observed pumping at one well negatively affects the other. In this analysis, we sought to understand how pumping at Glenn Ranch Well affects pressure at Mitigation Well, Slaughter House Ranch Well, and Middle Well. Therefore, we are mostly interested in the cross-correlation at zero to negative lags (i.e., when the weekly cumulative gallons pre-dates inferred weekly pressure readings). This implies a lag effect between them, such that pumping from Glenn Ranch Well affects pressure at the other wells sometime after or within that same week. The cross correlation analysis allows us to determine what lag to use in the dynamic linear model. Given that data is on a weekly time step, then the lag is on a current week or 1 or 2 week delay.

The highest cross correlation between Glenn Ranch Well and Mitigation Well was at 0 (the same week), and thus indicates that a high producing week at Glenn Ranch Well will lead to a below average value of “pressure” about that same week at Mitigation Well (Figure 5). Additionally, the highest cross correlations between Glenn Ranch Well and Slaughter House Ranch Well and Middle Well were between -1 and -3 weeks. This means that these analysis can detect activities at Glenn Ranch Well, likely explaining the immediate impacts observed not only at Mitigation Well but also at two newly monitored wells (i.e., Slaughter House Ranch Well and Middle Well) (Figures 6 and 7).

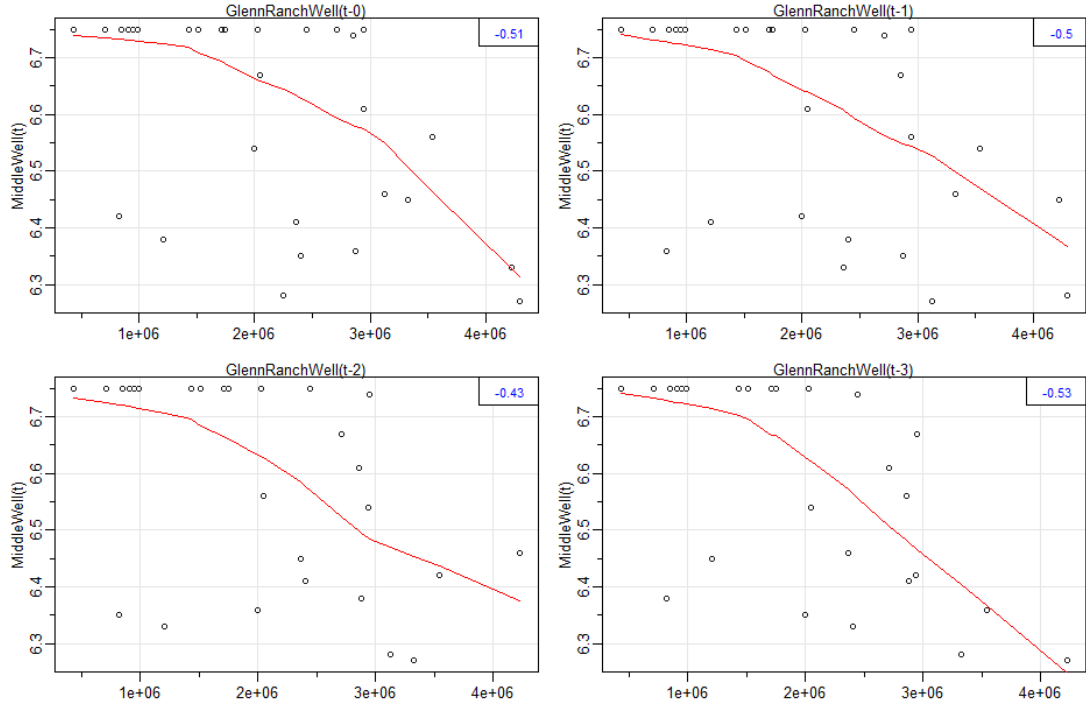


**Figure 5.** Lag plot between the current weeks pumping (t-0) to a lag of three (t-3) weeks pumping at Glenn Ranch Well and pressure readings at Mitigation Well located at San Bernardino National Wildlife

Refuge. The correlations (top right hand corner) range from -0.45 to -0.66, meaning that the relationship is significantly negative.



**Figure 6.** Lag plot between the current weeks pumping (t-0) to a lag of three (t-3) weeks pumping at Glenn Ranch Well and pressure readings at Slaughter House Ranch Well. The correlations (top right hand corner) range from -0.56 to -0.66, meaning that the relationship is significantly negative.



**Figure 7.** Lag plot between the current weeks pumping (t-0) to a lag of seven (t-3) weeks pumping at Glenn Ranch Well and pressure readings at Middle Well at San Bernardino NWR. The correlations (top right hand corner) range from -0.43 to -0.53, meaning that the relationship is significantly negative.

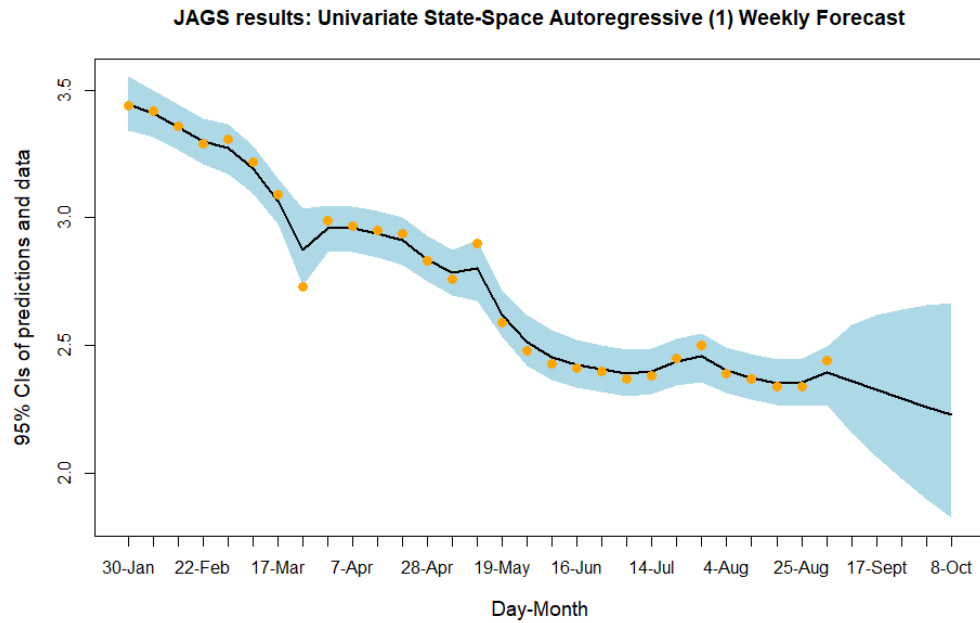
To estimate if these relationships are statistically significant using the identified lags for Mitigation Well, Slaughter House Ranch, and Middle Well, we modeled the time series as a dynamic linear model. We did this by developing a set of models relating pumping from Glenn Ranch Well with the average pressure readings at Mitigation Well over the same time period (e.g., week) in accordance to the cross-correlation analysis (Figures 5-7). We also did this for the other two wells, respectively. From the statistical models, all coefficients were statistically significant. Irrespective of the Well, there is a significantly negatively trend among the pressure readings at each of these Wells and cumulative pumping activities at Glenn Ranch Well.

In Figure 5, the correlation value for the time series ranges between -0.50 to -0.70. The  $R^2$  values for the dynamic statistical models (the linear model discussed above) that describes the relationship between the highest lag and pumping (e.g., lag of one week) ranged between 0.37 and 0.42 (Table 2). This means that between 37% and 44% of the variation observed in pressure readings at these Wells is explained by the current or past weeks pumping at Glenn Ranch Well. The results from the statistical model that represents the overall best model for each Well are presented below.

Table 2. Results from the best fit statistical model for each Well.

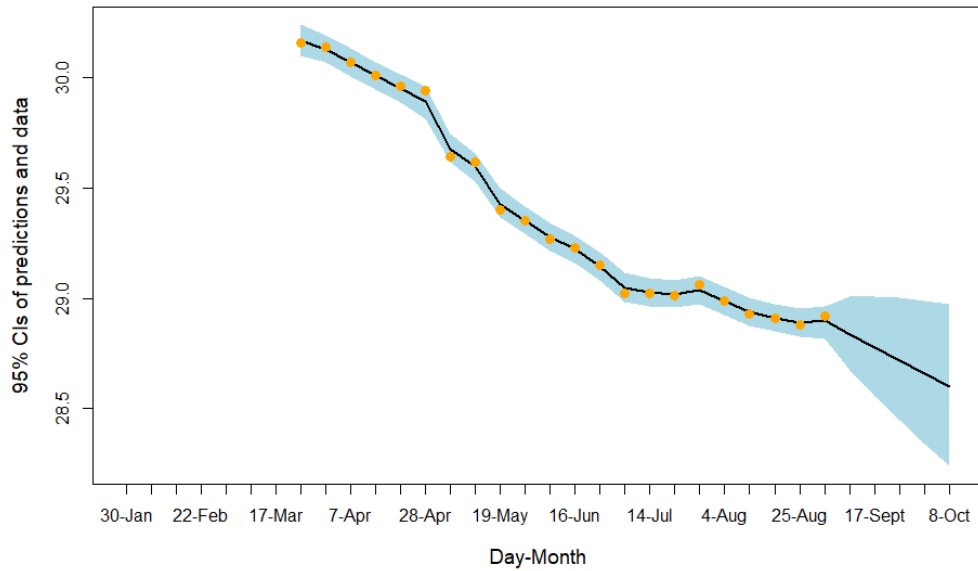
Well	Lag	Coefficients	Estimate	Standard Error	p-value	$R^2$
Mitigation Well	Current week (t-0)	Intercept	3.268	1.23E-01	<2.0e-16	0.42
	Current week (t-0)	Slope	-2.39E-07	5.18E-08	8.86E-05	
Slaughter House Ranch Well	Three weeks (t-1)	Intercept	3.03E+01	1.64E-01	<2.0e-16	0.44
	Three weeks (t-1)	Slope	-3.27E-07	6.94E-08	7.29E-05	
Middle Well	Six weeks (t-3)	Intercept	6.809	6.44E-02	<2e-16	0.37
	Six weeks (t-3)	Slope	-1.15E-07	2.89E-08	5.77E-04	

Lastly, we fit an autoregressive time series model of order 1 (i.e., AR(1)), which incorporates a parameter that controls the degree to which the data varies to project through time. Autoregressive order 1 models typically only account for uncertainty due to process error (also interpreted as natural variation). Therefore, we fit a Bayesian state space model with an autoregressive order-1 error to account for both process error and observation error (also interpreted in measurement error in pressure readings) by constructing a model that estimates the unseen states, such as the first pressure reading in the time series, to the observed data. The models fit the data well and indicates a significant decline in weekly average pressure readings since January (or since the first recorded pressure reading) (Figures 8-10).

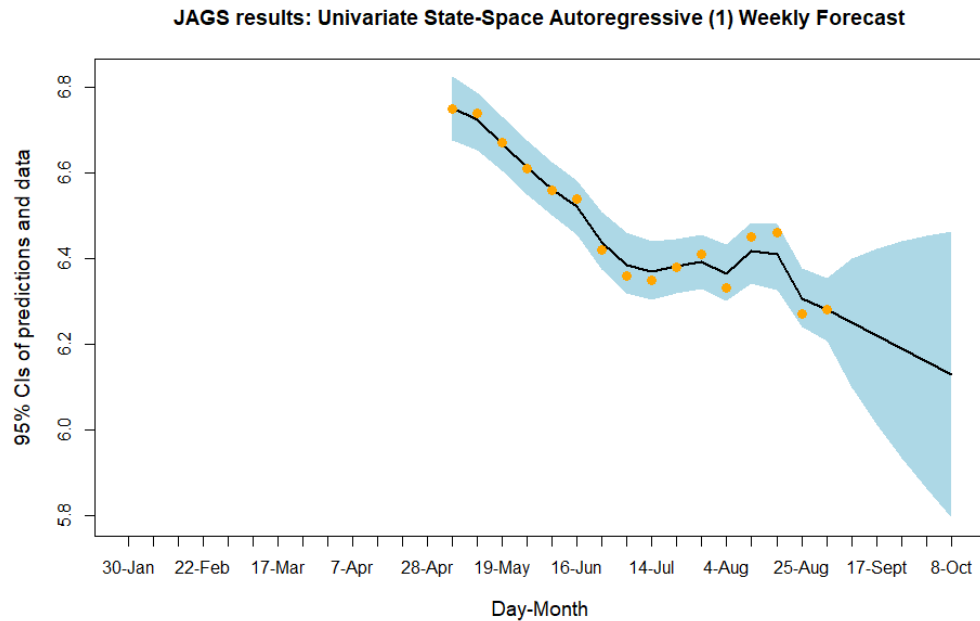


**Figure 8.** Bayesian state-space model with process model autoregressive (AR(1)) model predictions (black line), 95% credibility bounds (blue polygon), and average weekly pressure readings (orange points) for Mitigation Well located at San Bernardino NWR. Day-Month represents the first day of the weekly readings. The black line with no associated observations (orange points) represents the forecast of average weekly pressure readings to the week of October 8<sup>th</sup>.

JAGS results: Univariate State-Space Autoregressive (1) Weekly Forecast



**Figure 9.** Bayesian state-space model with process model autoregressive (AR(1)) model predictions (black line), 95% credibility bounds (blue polygon), and average weekly pressure readings (orange points) for Slaughter House Ranch Well. Day-Month represents the first day of the weekly readings. The black line with no associated observations (orange points) represents the forecast of average weekly pressure readings to the week of October 8<sup>th</sup>.



**Figure 10.** Bayesian state-space model with process model autoregressive (AR(1)) model predictions (black line), 95% credibility bounds (blue polygon), and average weekly pressure readings (orange points) for Middle Well located at San Bernardino NWR. Day-Month represents the first day of the weekly readings. The black line with no associated observations (orange points) represents the forecast of average weekly pressure readings to the week of October 8<sup>th</sup>.

Conclusion: These analyses provide continued evidence that pumping at Glenn Ranch Well is significantly impacting wells located at San Bernardino National Wildlife Refuge, leading to immediate and significant loss in pressure. Our analysis indicates that the activities at Glenn Ranch Well can be detected at less than a week and up to six weeks after. This correlates with why some ponds at the Refuge are void of water, and why it is so difficult to maintain water levels at 11 of 21 ponds that currently have threatened and endangered fish species. Additionally, our forecasts indicate that the consequences of the activities at Glenn Ranch Well will be observed in the foreseeable future, meaning that pressure readings will continue to be too low to support historical pond water levels. And thus, the current state at the Refuge and what it takes by staff to support the species and ponds will continue into the future.

The short-term effects of this water withdrawal are known. The USFWS has observed ponds that no longer have water and are completely dry, and San Bernardino NWR is having difficulty keeping some ponds filled with water because of the reduced artesian flows. In July 2020, a sample of 20 dead fish were collected by refuge staff from a drying pond as part of fish salvage operations related to reduced water levels at San Bernardino NWR. Twenty dead Yaqui

Beautiful Shiner were transferred to the Southwestern Native Aquatic Resources and Recovery Center Southwestern Fish Health Unit for parasite screening and National Wild Fish Health Survey testing. Assays and examinations for the sampled fish included virology, bacteriology, and parasitology for listed pathogens along with additional checks for external parasites. Testing was performed per the American Fisheries Society-Fish Health Section Bluebook (2016 edition) and standard Southwestern Fish Health Unit protocols. The results of the screening and testing indicated that no targeted viral, bacterial or parasitic pathogens were isolated from any of the 20 dead Yaqui beautiful shiner, nor no external parasites were observed on the skin or gills of the fish. These results suggest that the death of these is likely contributed to changing water conditions and reduced water levels at San Bernardino NWR. The long-term effects of continued water extraction are unknown; it is unclear whether or not the aquifer will rebound from the withdrawals that are currently occurring, or how long such a process may take.

Additionally, habitat destruction in Mexico is also considered great due to overall water withdrawal for agriculture and municipal uses (Miller et al. 2005, Fagan et al. 2005). The destruction and modification of beautiful shiner habitat has slowed or even been reversed in the U.S. portion of the species range as a result of the focus provided by recovery activities. Water development remains an issue in the lower portion of the Mimbres River Basin. Some steps are being put into place for fish passage around diversion structures, but dewatering still occurs downstream of San Lorenzo. Wetland-specific habitat protection, restoration, and maintenance have been pursued by the Fish and Wildlife Service at San Bernardino and Leslie Canyon National Wildlife Refuges.

At the watershed scale, protection of the U.S. portion of the upper Rio Yaqui has been greatly assisted by the creation and involvement of the Malpai Borderlands Group, as an organization of landowners that covers about 1 million acres and that is focused on open-space protection and watershed restoration (Curtain 2007). In Mexico, the Cuenca los Ojos foundation has purchased and protected many thousand acres of the Upper Rio Yaqui, but long-term legal protections are questionable (e.g., governmental expropriation of property for development).

Habitat destruction for freshwater fishes, including beautiful shiner, includes direct effects such as groundwater pumping and water diversion, and indirect effects such as climate change. Destruction and dewatering of rivers in Mexico continues (Miller et al. 2005, Fagan et al. 2005) and presents a direct threat. Matthews and Zimmerman (1990) described potential direct (e.g., water warming) effects of climate change on fishes of the southwestern U.S. The IPCC (2007) described changing precipitation patterns at a global scale, and such

changes have the potential to detrimentally affect aquifer health and the beautiful shiner.

**2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:**

Overutilization of beautiful shiner for any purpose is unlikely.

**2.3.2.3 Disease or predation:**

Since the issuance of the original recovery plan in 1995, the invasive parasite Asian tapeworm has been discovered and monitored in Rio Yaqui fishes. Kline (2007) examined the effects of the tapeworm on Yaqui chub and topminnow, and found that the effects of infestation were generally limited. Tapeworm-infestation strongly affects a population shortly after introduction (i.e., there is strong selection pressure against the infected populations), but the continued existence of the parasite appears to be of minor consequence. In addition to the tapeworm, beautiful shiner are occasionally found to have yellow grub (*Clinostomum marginatum*) or eye trematodes, the overall health effects of which are unknown but likely minor.

**2.3.2.4 Inadequacy of existing regulatory mechanisms:**

Current regulatory mechanisms are not adequate in the U.S. portion of the species' range, where waivers of all environmental laws are being invoked for national security reasons. Regulatory mechanisms also deserve greater attention in Mexico—which comprises 98% of the Yaqui basin and the beautiful shiner's range—where topics from water law to endangered species legislation are too often weakly enforced (Fitzgerald et al. 2014).

**2.3.2.5 Other natural or manmade factors affecting its continued existence:**

Significant progress was made between 1995 - 2018 in protecting and recovering the Yaqui beautiful shiner in the U.S., although this progress is now threatened by ongoing construction of border security infrastructure. Additionally, habitat destruction and invasive species interactions continue to represent the greatest known threats to Guzman beautiful shiner in the Mimbres River and to the Yaqui beautiful shiner in Mexico, but, as discussed elsewhere in this review, large gaps exist in our knowledge of the species. Current data from the majority of the species' range in Mexico is needed to fully assess any additional factors influencing beautiful shiner existence. Lastly, recreational (i.e., bait) use of non-native red shiner (*Cyprinella lutrensis*) presents the threats of competition and inter-specific hybridization.

Hendrickson et al. (1981) discussed the potential threat at the watershed scale, but there is no current information to determine if the Red Shiner is even in the Rio Yaqui. Delisting criterion “b” loosely addresses the presence of non-native fish species at San Bernardino NWR.

## 2.4 Synthesis

Given the background and new information described above, we would first describe beautiful shiner status as uncertain: too much information is lacking from the majority of the species’ range in Mexico. Moreover, no systematic sampling for beautiful shiner in the Rio Yaqui has occurred in nearly 40 years, and thus we have no information on their current status in Mexico. Additionally, *Cyprinella bocagrande*, *Cyprinella formosa formosa*, and *Cyprinella formosa mearnsi* may be genetically divergent enough to be considered distinct subspecies. However, additional genetics research and assessment by the American Fisheries Society Names Committee would be useful in making this determination. If these entities were determined to be separate taxa, this could potentially change classification status and subsequent recovery planning and status reviews going forward.

Beautiful shiner have been reestablished at San Bernardino NWR, and their populations have been self-sustaining and secure in multiple San Bernardino NWR/Leslie Canyon NWR habitats since reintroduction in May 1990 – well past the 10 years identified in the recovery plan to meet delisting criteria. However, Guzman beautiful shiner have not yet been reestablished, self-sustaining, and secure for at least 10 years in the Mimbres River. Finally, self-sustaining populations of both forms are not secure within their historic ranges in Mexico, or populations have not been monitored to determine presence/absence.

Non-indigenous fish species have been successfully eradicated on San Bernardino NWR, Leslie Canyon NWR, and Slaughter Ranch (private property) since the 1990’s. USFWS personnel have surveyed annually and occasionally biannually and no longer observe any non-indigenous fish species at San Bernardino NWR, Leslie Canyon NWR, House Pond on Slaughter Ranch, and Big Tank on El Coronado Ranch. Though American bullfrogs (*Lithobates catesbeiana*), a non-native amphibian, remain and in adjacent wetlands, we believe this species poses little direct risk to beautiful shiner, though it may compete for limited food resources. Since the initial invasion of bullfrogs, the numbers of beautiful shiner have continued to remain stable and self-sustaining, indicating that bullfrogs do not pose a threat to the persistence of the beautiful shiner. However, non-indigenous species continue to pose a direct risk to beautiful shiner in Mexico.

Additionally, Earman et al. (2003) delineated catchment area, recharge and flow rates, storage volumes and other attributes of the underground aquifers for portions of the watershed that included San Bernardino NWR/Leslie Canyon NWR. Since the mid-1990’s, we also worked to identify and quantify the volume of water required to sustain the existing wetland ponds found throughout the refuge. For the past few decades, the annual impact to the aquifer appeared to be minimal, and the aquifer has demonstrated a pattern of natural recharge. This is expected to change, ongoing construction of 25 miles of border security infrastructure in the San Bernardino Valley is

anticipating the withdrawal of 700,000 gallons of water per day to support concrete production during the construction period (Department of Homeland Security and Environmental Protection Agency, email communication August 8, 2019). Additionally, destruction and dewatering of rivers in Mexico continues (Miller et al. 2005, Fagan et al. 2005) and presents a direct threat.

Problems exist with the 1994 Fishes of the Rio Yaqui Recovery Plan. These include the multi-species nature of the plan and dated background material. Recent evidence suggest that new recovery plans should be written for each individual Rio Yaqui fish species, and the Yaqui and Guzman beautiful shiner specifically as these species are genetically divergent and distinct subspecies. Although the Fishes of the Rio Yaqui Recovery Plan includes quantitative delisting criteria for beautiful shiner (Yaqui and Guzman), developing new delisting criteria for each species does not appear feasible given the lack of biological information and the continuing and new threats that have been identified. We do not yet understand population demographics, trends, and other data that would enable us to determine the number of populations or sizes of populations needed to define recovery of the beautiful shiner. There is also an absence of data throughout the range of beautiful shiner in Mexico and we have little knowledge of or influence on the management practices being pursued by officials in Mexico. Additionally, attaining an understanding of the Guzman beautiful shiner is needed, as this information is lacking.

We recommend maintaining beautiful shiner as threatened at this time, but we think that up-listing to endangered should remain an option if additional information indicates such action is warranted. We emphasize that data need to be gathered over the next five years to ensure an accurate assessment in the next status review. We know that the number of populations in the U.S. has risen from about three in 1994 to about 12 in 2019, demonstrating that greater attention and active management can produce valuable recovery results through an increasing and self-sustaining population in Arizona.

### 3.0 RESULTS

#### 3.1 Recommended Classification: Given your responses to previous sections, particularly section 2.4. Synthesis, make a recommendation with regard to the listing classification of the species

- Downlist to Threatened  
 Uplist to Endangered  
 Delist (*Indicate reasons for delisting per 50 CFR 424.11*):  
      Extinction  
      Recovery  
      Original data for classification in error  
 No change is needed

#### 3.2 New Recovery Priority Number (*indicate if no change; see Appendix E*):

No change.

**Brief Rationale:** Beautiful shiner has an RPN of 2, indicating that threats to this species

are of high magnitude and are imminent. An RPN of 2 remains applicable.

#### 4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The foremost recommendation for action is that we update our knowledge of beautiful shiner status in the Rio Yaqui and Guzman basin: no new data have been collected since 1994 (Rio Bavispe area; Abarca et al. 1995), and no system-wide surveys have been conducted since those of Hendrickson et al. (1981). In addition to distribution surveys of beautiful shiner in the Rio Yaqui basin, the Guzman beautiful shiner from the Guzman basin need to be sampled. New distributional data are needed to make informed decisions regarding the distributional boundaries of the beautiful shiner complex.

The second recommendation for action is that we refine our understanding of the life history characteristics and habitat requirements of beautiful shiner. The species' apparent rarity has made quantitative analysis difficult, but a concerted effort to collect observational and experimental data would greatly benefit our knowledge base. The life history and ecological characteristics of beautiful shiner are important not only in executing recovery actions, but also in refining recovery criteria.

When possible, given workloads, a Species Status Assessment should be conducted to guide the development of a recovery plan revision. We recommend a recovery plan be written for both the Yaqui and Guzman beautiful shiner as these are distinct subspecies and not be included in a bundled plan. Lastly, the new recovery plan should provide up-to-date information on populations of this small desert cyprinid.

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**U.S. FISH AND WILDLIFE SERVICE**  
**5-YEAR REVIEW of *Cyprinella formosa***

**Current Classification:** Threatened

**Recommendation resulting from the 5-Year Review:**

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change needed

**Appropriate Listing/Reclassification Priority Number, if applicable:**

**Review Conducted By:** San Bernardino National Wildlife Refuge, Douglas, Arizona

**FIELD OFFICE APPROVAL:**

**Lead Field Supervisor, Fish and Wildlife Service**

Approve \_\_\_\_\_