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DISTRIBUTION AND NOTES ON THE BIOLOGY OF ZUNI BLUEHEAD SUCKER, *CATOSTOMUS DISCOBOLUS YARROWI*, IN NEW MEXICO

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ABSTRACT—Zuni bluehead sucker, *Catostomus discobolus yarrowi*, is endemic to the Little Colorado River drainage of west-central New Mexico and east-central Arizona. The extent of its historical distribution is uncertain, but included several tributaries of the Little Colorado River upstream of Grand Falls, Arizona; origin of the taxon is ambiguous and contributes to poor definition of its former distribution. Fish eradication efforts in the 1960s eliminated the subspecies from portions of the Zuni River drainage in New Mexico. Surveys in New Mexico during 1990 through 1993 found it in about 15 km of Río Nutria headwaters. Zuni bluehead sucker persists where habitat degradation (channel incision and sedimentation) is limited and nonnative fishes (particularly *Lepomis cyanellus*) are rare or absent. Seasonally dry channels and low waterfalls limited movement among headwaters. We found the sucker most commonly in low-velocity (<10 cm/sec), moderately deep (0.3 to 0.5 m) pools and pool-runs with seasonally dense perilithic and periphytic algae. Life history studies (1994 and 1995) documented reproduction in spring (April through early June) when water temperature was 6 to 13°C. Based on length-frequency data, some individuals matured by age 1 and most were mature by age 2. Females typically produced 400 to 600 ova annually; spawning may be bimodal, with most occurring early in the season. Individuals may attain 50 to 60 mm SL in their first year (age 0), thereafter growth is about 30 to 40 mm per year. Few suckers were >150 mm SL and most individuals were ≤age 3; few survived to age 4. Survival of Zuni bluehead sucker without intensification and expansion of current conservation efforts is doubtful.

RESUMEN—El matalote de cabeza azul del Zuni, *Catostomus discobolus yarrowi*, es una especie endémica de la cuenca del Río Little Colorado de la parte oeste-central del estado de Nuevo México y la parte oriente-central de Arizona. La amplitud de su distribución histórica no es bien conocida, pero incluyó tributarios del Río Little Colorado arriba de Grand Falls, Arizona. El origen del taxón es ambigüo y contribuye a la definición inadecuada de su distribución histórica. Esfuerzos para erradicar peces en la décado de los 1960 elminaron la subespecie de partes de la cuenca del Río Zuni en Nuevo México. Muestreos en Nuevo México durante de 1990 a 1993 la encontraron en aproximadamente 15 km de los nascientes del Río Nutria. El matalote de cabeza azul del Zuni persiste donde la degradación del hábitat (incisión del cauce y sedimentación) es limitada y peces no nativos (particularmente *Lepomis cyanellus*) son raros o ausentes. Cauces que se secan y cascadas bajas limitaron movimiento entre los arroyos de los nascientes. Encontramos al matalote típicamente en pozas de baja velocidad (<10 cm/sec), profundidades moderadas (0.3 a 0.5 m) y en corridas ("runs") con algas perifíticas y perilíticas estacionalmente densas. Estudios de historia de vida (1994 y 1995) documentaron la reproducción en la primavera (abril a principios de junio) cuando la temperatura del agua estaba entre 6 a 13°C. Basado en datos de frecuencias de tallas, algunos individuos maduraron en su primer año, y la mayoría maduró en año 2. Las hembras produjeron típicamente de 400 a 600 huevos anuales; el desove puede ser bimodal, con la mayoría desovando temprano en la época. Individuos alcanzan de 50 a 60 mm LE en su primer año (edad 0), y después el crecimiento es aproximadamente de 30 a 40 mm/año. Pocos matalotes sobrepasaron 150 mm LE y la mayoría era de menos de 3 años de edad; pocos sobrevivieron a la edad 4. La persistencia del matalote de cabeza azul del Zuni es dudosa sin que se intensifiquen y se aumenten los esfuerzos actuales de conservación.

Zuni bluehead sucker, *Catostomus discobolus yarrowi,* is endemic to headwaters of the Little Colorado River, east-central Arizona and west-central New Mexico. Origin of this taxon is ambiguous. Smith (1966), although eschewing taxonomic recognition of the form (retaining it as *C. discobolus,* based on number of gill rakers), provided morphological and meristic evidence for its hybrid origin. He speculated capture of a Río Grande headwater by a Little Colorado River stream in the late Pleistocene enabled Río Grande *C. plebeius* to enter the latter and introgress with resident bluehead sucker. Smith also demonstrated an irregular downstream gradient, in tributaries of the Little Colorado River, of decreasing *C. plebeius* and increasing *C. discobolus,* postulating the proportion of *C. plebeius* was variable among downstream populations because of varying degrees of temporal and spatial isolation from headwater reaches. He discounted human translocation as an origin of the form because it was first collected in 1873. Using genetic and additional morphological and meristic data, Smith et al. (1983) concluded that distinctiveness of populations in the Zuni River reflected natural introgression of *C. plebeius* and *C. discobolus* and that contact was via headwater exchange. Based on cladistic relationships (Smith and Koehn, 1971), Smith et al. (1983) also concluded that Zuni River suckers merited recognition as *C. d. yarrowi.*

Although not disputing validity of that decision, Crabtree and Buth (1987) provided new allozymic data supporting a contention that *C. discobolus* in the upper Little Colorado drainage was distinguishable as *C. d. yarrowi* without genetic influence of *C. plebeius,* and that introgression of the two had occurred only in Río Nutria. They believed the shared morphological characters discussed by Smith et al. (1983) represented retained primitive traits of a common ancestor.

Sublette et al. (1990) cited articles 32 and 33 of the International Code of Zoological Nomenclature in justifying use of the subspecific epithet *jarrovii.* Eschmeyer et al. (1998:808), however, stated the change from *C. d. jarrovii* to *C. d. yarrowi* by Jordan and Copeland (1876–1877) was "perhaps unjustified," but nonetheless recognized *C. d. yarrowi,* which we apply, as the acceptable name for Zuni bluehead sucker.

The paucity of collections makes accurate characterization of the historical distribution of Zuni bluehead sucker problematic. In 1873, specimens described as *Minomus jarrovii* (Cope, 1874:135) were incorrectly attributed to "near Provo," Utah. Cope and Yarrow (1875) corrected the type locality to Zuni River, New Mexico. Although records are ambiguous, the form apparently was collected next in 1926 from Zuni River, near Zuni Pueblo (Museum of Southwestern Biology; MSB 2431); in 1948 and 1960, W. J. Koster (University of New Mexico) found it in ríos Pescado and Nutria, respectively (MSB 2434, 2637, 3108, and 3664).

Although not designated as *C. d. yarrowi,* Smith (1966) documented occurrence of bluehead sucker in Little Colorado River headwaters in Arizona (Show Low and East Clear creeks and an unnamed stream near Holbrook) and its persistence in ríos Nutria and Pescado in New Mexico. F. A. Winter (in litt.) reported that Agua Remora (formerly Radosevich Creek) was stocked with "minnows" (likely Zuni bluehead suckers) from Río Nutria by two Radosevich boys in the 1920s, but there is no substantive reason to doubt natural occurrence of Zuni bluehead sucker in the stream. Application of rotenone and toxaphene (27 treatments) in the 1960s and early 1970s to eliminate nonnative green sunfish (*Lepomis cyanellus*) and fathead minnow (*Pimephales promelas*) from Río Nutria undoubtedly killed many suckers (F. A. Winter, in litt.; Sublette et al., 1990). Winter (in litt.) attributed its persistence following piscicide treatments to dispersal from Agua Remora. The first effort to document the range of Zuni bluehead sucker in New Mexico was in 1978 and 1979 (B. Hanson, in litt.). He found 3 concentrations, Agua Remora, upper Río Nutria, and confluence of ríos Nutria and Pescado, and reported it rare or absent elsewhere in the drainage. Smith et al. (1983) confirmed its persistence in the ríos Pescado and Nutria and Agua Remora, and reported its absence from previously occupied Arizona streams (except East Clear Creek) and occurrence in Kin Li Chee Creek.

Accepting Crabtree and Buth's (1987) interpretation, Zuni bluehead sucker historically (pre-1875) occurred in headwaters of much of the Little Colorado River drainage upstream of Grand Falls, Arizona. If, however, the view of

Smith et al. (1983) is accepted, its historical range was limited to the uppermost Little Colorado drainage, primarily Zuni River and tributaries in New Mexico. Western populations were mainly another form of *C. discobolus* with diminishing *C. plebeius* traits up- to downstream. The issue may be unresolvable because Smith et al. (1983) found no *C. discobolus* at any Arizona site except Kin Li Chee Creek (but see Minckley, 1973).

In addition to Zuni bluehead sucker, the native fish fauna of the Zuni River drainage in New Mexico consisted of roundtail chub, *Gila robusta,* and speckled dace, *Rhinichthys osculus* (Sublette et al., 1990). Although these authors accepted the type locality for bonytail, *Gila elegans,* as the Zuni River, New Mexico, its historical occurrence there is doubtful (Smith et al., 1983). That species is an obligate large-river form, unlikely to inhabit the Zuni River. Others have considered the 1851 record (Baird and Girard, 1853) a consequence of mislabeling specimens (e.g., Smith et al., 1983), but the confusion also may result from the Territory of New Mexico not being divided into territories of Arizona and New Mexico until 1863. Since its initial collection in 1851, roundtail chub was collected in the Zuni River drainage in 1873 (United States National Museum; USNM 256) but not subsequently.

Despite its intriguing origin, listing as endangered by New Mexico (Propst, 1999), and as a species of special concern by Arizona (Arizona Game and Fish Department, in litt.) and the American Fisheries Society (Williams et al., 1989), little research or management attention has been given to Zuni bluehead sucker. Our study was undertaken to obtain information on the current distribution and biology of the species.

STUDY AREA AND METHODS—The ríos Nutria and Pescado arise along the Continental Divide in the Zuni Mountains of west-central New Mexico, then join to form the Zuni River that flows westward and southwestward to join the Little Colorado River in east-central Arizona (Fig. 1). Upper reaches of the drainage are at elevations between 2,280 and 2,515 m and 2,000 m where the Zuni River exits New Mexico. Several small impoundments interrupt streams in valleys. Continuous flow was present only during spring runoff or following summer storms. Streams emanate from meadow springs and thence most flow through canyon-bound reaches with moderate gradient (2.8%) and exposed, bedrock-dominated substrata. Pools (<1.0 m deep), separated by low (<1.0 m) waterfalls, and pool-runs are the most common habitat. Downstream, in alluvial valleys, gradient is slight (0.4%), and substrata are mainly sand and silt; large deep pools (many ca. 2.0 m) connected by intermittent flow are common.

Museum records, agency reports, and published literature were reviewed to determine the likely historical distribution of Zuni bluehead sucker in New Mexico. Museum records were provided by Academy of Natural Sciences, Philadelphia (ANSP), Arizona State University (ASU), University of Michigan Museum of Zoology (UMMZ), University of New Mexico Museum of Southwestern Biology (MSB), and United States National Museum (USNM). Recent distribution information was obtained from F. A. Winter (1979, Zuni mountain sucker habitat management plan, United States Department of Agriculture Forest Service, Cibola National Forest, Albuquerque, New Mexico) and B. Hanson (1980, Fish survey of the streams in the Zuni River drainage New Mexico, United States Fish and Wildlife Service, Region 2, Albuquerque, New Mexico).

Sampling to document the current New Mexico distribution of Zuni bluehead sucker began in 1990 and continued through 1993. All aquatic habitats that might support fishes were sampled. In streams, one sampling pass in an upstream direction, using battery- or generator-powered backpack electrofishers (direct current) to stun fishes, was made at each sample site. Each site was 75 to 100 m in length and included all available habitat types (e.g., pool, run, and riffle). All fishes were identified, weighed (± 0.1 ≤ 10 g and ± 1.0 >10 g), and measured (± 1.0 mm total [TL] and standard [SL] lengths). Suckers were returned alive to the stream near the point of capture. Nonnative fishes captured in streams were preserved and accessioned to the New Mexico Department of Game and Fish Collection of Fishes. Seines (4.5 by 1.8 m, 3 mm mesh) were used to sample 7 springs.

Habitats at each stream site were classed by location within the wetted channel, water depth and velocity, and cover (e.g., organic debris, boulders, undercut banks). Substrata were classified (following the general scheme of Cummins, 1962) as silt, sand, gravel, cobble, boulder, or bedrock. Water velocity (cm/sec) was determined with a Marsh-McBirney flowmeter mounted on a topset rod at 0.6 of depth (m). Water temperature (°C), dissolved oxygen (mg/l), and specific conductance (μmho/cm) were measured at each stream site with YSI meters.

Specimens collected in July 1994 were used to characterize non-reproductive season demographic attributes (i.e., length-weight relationship, size-structure, and relative condition) of 5 populations (Tampico Spring, Agua Remora, Silva, Nutria-Tampico,

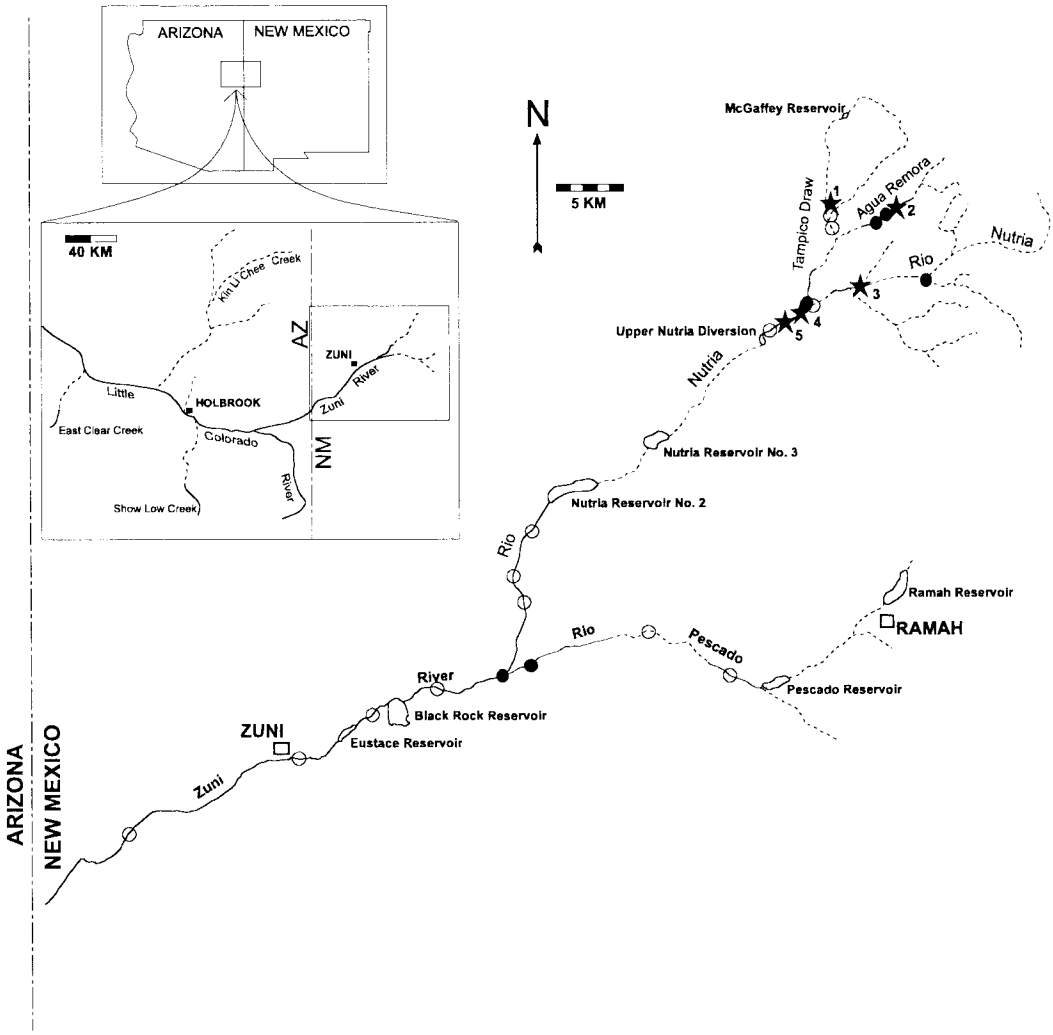

FIG. 1—Distribution of Zuni bluehead sucker in the Zuni River drainage of west-central New Mexico, 1990 through 1995. Circles indicate sample sites (open = absence, solid = presence of Zuni bluehead sucker). Stars indicate life history study sites: 1 = Tampico Spring, 2 = Agua Remora, 3 = Silva, 4 = Nutria-Tampico, and 5 = Nutria Box.

and Nutria Box). In 1995, specimens to characterize reproductive biology were collected at 2 sites (Silva and Nutria-Tampico) at 2-week intervals during the presumed reproductive season (early April through early June). Specimens collected in July 1994 were weighed, measured, and released. For reproductive studies, 10 mature specimens of each sex (determined by color, tuberculation, and expression of gametes) were desired from each site and visit, but if retaining 20 specimens was deemed excessive (based on number of mature fishes captured), fewer were kept. Impassable roads prevented access in mid April, equipment malfunction precluded sampling in early May at Silva, and fish were not kept in mid May because of low numbers captured. Specimens retained were euthanized with tricaine methanesulfanate (MS-222), fixed in 10% formalin, and transported to the laboratory for processing.

Retained specimens were weighed, measured, eviscerated, and total wet mass (±0.01 g) of reproductive organs of each female determined. Each ovary was divided into 3 roughly equal sections, ova in a weighed subsection of each section were enumerated, diameter of each ovum was measured (±0.1 mm). Stage of ovum maturation was characterized as: 1) immature = mean ova diameter < 0.5 mm,

TABLE 1—Occurrence of fishes in the Zuni River drainage, New Mexico. Data for all periods, except 1990 through 1995, derived from museum records and unpublished agency reports. Records for 1990 through 1995 from this study.

	Native			Nonnative					
Years	*Gila robusta*	*Rhinichthys osculus*	*Catostomus discobolus yarrowi*	*Esox lucius*	*Pimephales promelas*	*Oncorhynchus mykiss*	*Fundulus zebrinus*	*Lepomis cyanellus*	*Micropterus salmoides*
≤1900	X	X	X						
1901–1970		X	X		X			X	
1971–1989		X	X	X	X	X	X	X	X
1990–1995		X	X	X	X		X	X	

transparent; 2) early-maturing = mean diameter 0.5 to 1.0 mm, white and opaque; 3) late-maturing = mean diameter 1.0 to 1.5 mm, cream-colored and opaque; and 4) mature = mean diameter > 1.5 mm, orange and translucent. Total number of ova in each maturation stage in each female was estimated by the formula: (subsection mass/proportion of maturation stage in subsection) × (number of ova per maturation stage) × (section mass) × (total ovary mass). A gonadosomatic index (GSI = [ovary mass/body mass] × 100) was calculated for each female. Individuals having ≤100 late-maturing or mature ova were excluded from analyses.

Exponential length-mass relationships ($M = aSL^b$) were calculated for July 1994 samples and compared among populations; specimens were not separated by sex. Specimens were grouped into 10-mm length-classes in length-frequency histograms to characterize population size- and age-structure. To compare relative condition or well-being of populations, Fulton condition coefficients ($K = mass/SL^3 \times 10^6$) were calculated for each length-class in each sample. Values for length-classes that lacked specimens were estimated from the calculated length-mass relationship for that sample. We used the Fulton condition index because our calculated length-mass relationships indicated that Zuni bluehead sucker had near-isometric growth (Ricker, 1975).

Student's *t*-test was used to compare SL of mature males and females during the reproductive season. Regression analysis was used to characterize relationships between female SL and number of late-maturing and mature ova. Male:female ratios were compared using Chi-square analysis. Analysis of covariance (ANCOVA), with SL the covariate, was used to compare length-mass relationships of suckers (sexes combined) from 5 sites (Tampico Spring, Agua Remora, Silva, Nutria-Tampico, and Nutria Box) sampled in July 1994, and males and females from Silva and Nutria-Tampico during the 1995 reproductive season. If ANCOVA indicated significant differences, a post-hoc test (Tukey Honest Significant Difference for unequal sample sizes) was used to determine which samples were significantly different in multiple comparisons (Zar, 1984). If ANCOVA did not yield significant differences, analysis of variance (ANOVA) was used to compare mass among samples. Post-hoc tests were used to identify significantly different samples. Analysis of variance was used to compare length-class condition among non-reproductive season samples (1994); post-hoc tests were performed to identify significantly different populations.

RESULTS—Our survey found Zuni bluehead sucker mainly in the Río Nutria drainage from the mouth of Nutria Canyon upstream (Fig. 1). Within this area it had a discontinuous distribution; it was most common in Río Nutria near the mouth of Nutria Canyon, the confluence of Río Nutria and Tampico Draw, upper Agua Remora, Tampico Spring, and upper Río Nutria. Several hundred fish typically were seen at these locations, but densities were noticeably lower elsewhere. Collectively, the above reaches totaled ca. 15 km of permanently-watered habitat. Suckers were irregularly captured in low numbers (≤10) in reaches near the confluence of ríos Pescado and Nutria. It was not found in the Zuni River downstream of the confluence of ríos Pescado and Nutria nor isolated springs. Surveys by Zuni Fish and Wildlife Department did not find the fish in impoundments (T. L. Stroh, pers. comm.).

We collected one specimen of speckled dace in the Río Pescado and found no roundtail chub (Table 1). Nonnative fishes were absent in most reaches occupied by Zuni bluehead sucker, but fathead minnow was in Tampico Draw and green sunfish was in uppermost Agua Remora. Green sunfish and plains killi-

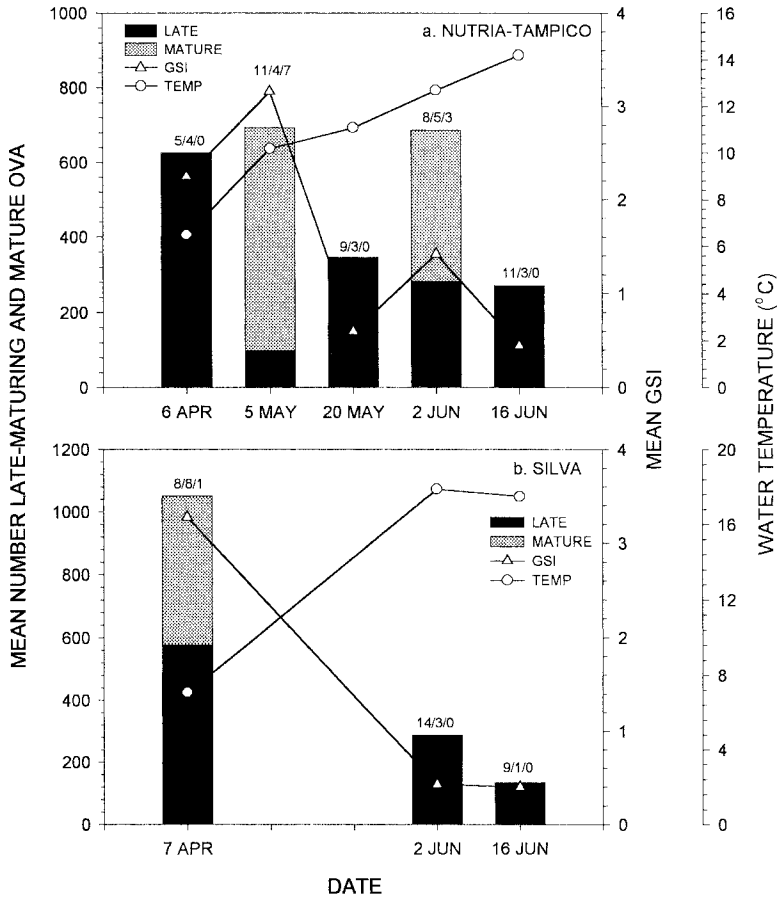

FIG. 2—Attributes of female Zuni bluehead suckers during reproductive season (5 April to 16 June 1995) at: a) Nutria Tampico and b) Silva. Height of each bar represents the sum of mean number of late-maturing and mature ova in females on each date. Numbers above each bar indicate number of females examined/number with late-maturing ova/number with mature ova. Females with <100 ova in either mode were excluded from mean number calculations. All females, regardless of number of late-maturing and mature ova, were used to calculate GSI.

fish (*Fundulus zebrinus*) were common where suckers were rare or absent. Northern pike (*Esox lucius*) was present in lower Río Nutria.

Zuni bluehead sucker was found most commonly in shaded pools and pool-runs (0.3 to 0.5 m deep) with water velocity ≤10 cm/sec. Substrata varied from gravel, cobble, and boulders to bedrock. Silt covered (1 to 3 cm) base substrata in pools during baseflow periods. Emergent aquatic plants (mainly *Typha*) edged pool and pool-run habitats. Perilithic and periphytic algae were seasonally dense in habitats where suckers were common. Dissolved oxygen varied between 4.5 and 8.5 mg/l in summer and up to 10.0 mg/l in spring. Specific conductance was usually 250 to 400 μmho/cm, but as high as 570 μmho/cm during summer.

Reproduction—Reproductively ripe, male Zuni bluehead suckers were intensely tuberculated on their anal fins and ventral lobe of caudal fin. Dorsally, such males were intense black with a bright red lateral band and white venter. Females were mottled slate-gray dorsally with cream-colored bellies. The abdomen of ripe females was noticeably distended.

On 6 April, 4 of 5 females from Nutria-Tampico had large complements of late-maturing ova, but none was mature (Fig. 2a); a 139 mm SL female had no late-maturing or mature ovum. One month later (5 May), the majority

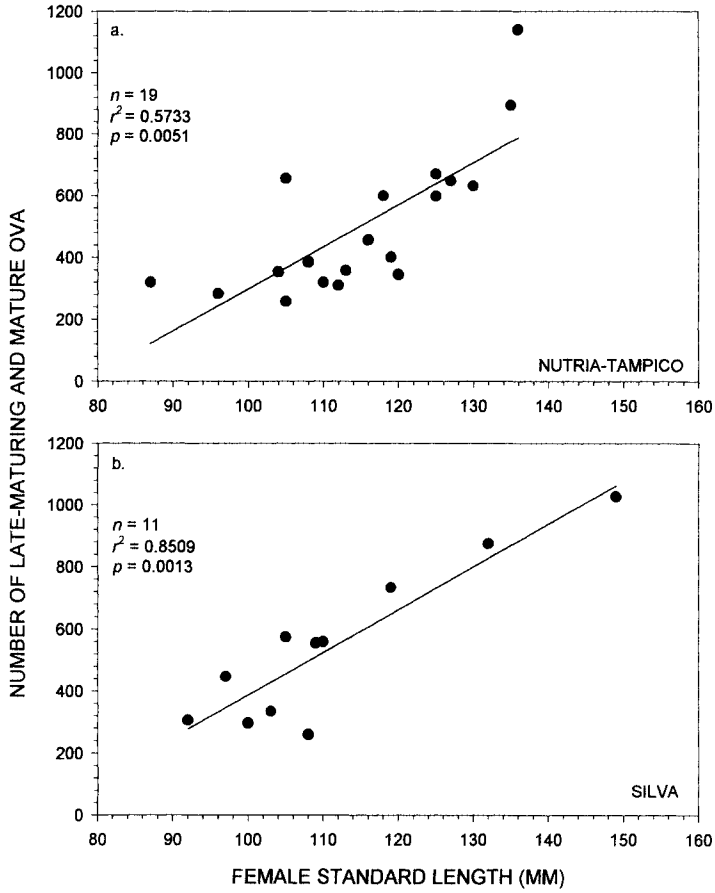

FIG. 3—Relationship between number of late-maturing and mature ova and SL of female Zuni bluehead suckers at: a) Nutria-Tampico and b) Silva, 5 April through 16 June 1995. Females with <100 late-maturing and mature ova excluded.

of ova (75 to 100%) in 6 of 11 females was mature, 1 had a small complement (16%) of mature ova, and 4 had no late-maturing or mature ovum. Of 9 females examined on 20 May, 2 had late-maturing ova, but 7 had no late-maturing or mature ovum. The sample from 2 June, however, yielded 2 females (of 8 examined) with >400 mature ova each; 3 of the remaining females had >300 late-maturing ova. On 16 June, 8 of 11 females had no late-maturing or mature ovum and 3 had late-maturing but no mature ovum. Each sample had at least 1 female with no late-maturing or mature ovum, but the largest proportion of such females occurred on 20 May (67%) and 16 June (72%). Mean GSI peaked on 5 May when water temperature was 10.1°C, and a second peak occurred on 2 June (water temperature = 12.7°C). Number of mature ova per female (excluding females with <100) ranged from 401 (SL = 119 mm) to 795 (SL = 135 mm). Number of late-maturing and mature ova was significantly related to female SL (Fig. 3a). Mean SL of females having >100 late-maturing and maturing ova on 6 April and 5 May was 119.5 (n = 11), but was 109.5 mm (n = 8) for the remaining sample dates; the difference was significant (t = 1.767, P = 0.047, df = 17).

On 7 April, all females examined (n = 8) at Silva had late-maturing ova and one (SL = 149 mm) had 472 mature ova (Fig. 2b). Neither June sample yielded females (n = 14 and 9) with mature ova, and only 3 on 2 June and 1 on 16 June had late-maturing ova. Female SL was significantly related to number of mature and maturing ova (Fig. 3b).

TABLE 2—Sex of Zuni bluehead suckers collected at Nutria-Tampico and Silva in Zuni River drainage, New Mexico, 6 April 1995 through 16 June 1995.

	Nutria-Tampico			Silva		
Size-class (mm, SL)	Male	Female	Unknown	Male	Female	Unknown
60–69	0	0	20	1	1	9
70–79	4	3	19	12	0	7
80–89	10	7	10	18	15	3
90–99	17	7	3	21	8	1
100–109	17	7	0	14	11	1
110–119	19	14	1	6	3	0
≥120	13	24	0	5	6	0
Total	80	62	53	77	44	21

Data from Nutria-Tampico suggest spawning by Zuni bluehead sucker could be bimodal (Fig. 2a), with most ova produced early in the season. On 5 May, mature ova were 75% or more of the late-maturing/mature count in 6 females (11 examined); mature ova were 16% of the count in a seventh fish. Two weeks later, no female (n = 9) had mature ova, and only 1 had >100 late-maturing ova. On 2 June, 3 (of 8 examined) had mature ova; 1 had only 30, but 2 had ca. 400 each. Mean GSI (0.604) and percent females having no ova (67%) in the late-maturing or mature mode was lower on 20 May than the preceding and succeeding dates. Mean SL of females having mature ova in early May was not significantly different from that of early June (t = 0.627, P = 0.564, df = 4). Absence of late-April and May collections from Silva precludes consideration of possible spawning bimodality at the site.

During the spawning season, sex was determined for a few individuals between 60 and 69 mm SL from both sites (Table 2). Between 70 and 99 mm SL, sex of a majority could be determined, and that for almost all suckers ≥100 mm SL. Males outnumbered females in all size-classes, except the largest (≥120 mm SL), at both sites. Overall sex ratios at Nutria-Tampico (1.29:1.00) and Silva (1.75:1.00) were each significantly different (χ^2 = 37.02, P < 0.001, df = 6 and χ^2 = 25.71, P < 0.001, df = 6, respectively). Mature males (n = 80) varied from 73 to 212 mm SL (mean = 106.1), and females (n = 62) were 73 to 160 mm SL (mean = 113.6) at Nutria-Tampico; SL was significantly less in males than females (t = −2.154, P = 0.033, df = 140). At Silva, males were from 65 to 140 mm SL (n = 77, mean = 94.0), and females were 68 to 156 mm SL (n = 44, mean = 100.1); the difference was not significant (t = −1.961, P = 0.052, df = 119). Both males and females from Nutria-Tampico were significantly larger than those from Silva (t = 4.362, P = 0.001, df = 155 and t = 3.310, P = 0.001, df = 104, respectively). At both sites, females had significantly greater mass (SL = covariate) than males (F = 8.484, P = 0.004, df = 139 at Nutria-Tampico and F = 13.1, P < 0.001, df = 118 at Silva). Reproductive season length-mass relationships reflected this difference (Fig. 4a).

Population Demographics—The size-structure of 5 populations sampled in July 1994 indicated that age 0 fishes ranged from less than 20 mm SL (Fig. 5a; Tampico Spring) to ca. 50 mm SL (Fig. 5d; Nutria-Tampico) by mid-summer. Age 0 individuals were 5% (Fig. 5c; Silva) to 21% (Fig. 5d; Nutria-Tampico) of each population in July 1994. All fish collected at Agua Remora (Fig. 5b) in July 1994 were ≥40 mm SL. A second peak in abundance at the 70 to 79 or 80 to 89 length-class was evident for Tampico Spring, Silva, and Nutria-Tampico; thus, individuals between about 60 and 90 mm SL were likely age 1. The second peak for the Nutria Box sample was the 50 to 59 mm length-class (Fig. 5e). At Nutria-Tampico, subsequent peaks were between 100 and 119 mm (age 2) and at the 130 to 139 mm length-class (age 3).

On 6 April 1995, the length-frequency histogram of the Nutria-Tampico population indicated 2, perhaps 3, age-classes of suckers (Fig. 5f); age 1 individuals were 50 to 89 mm SL, and age 2 were 90 to 119 mm SL. Fish in the 130 to 139 length-class were likely age 3. Annual growth increments were 30 to 40 mm for fish from their second (age 1) through fourth (age 3) years. Using these age-class size ranges, 8 (4 males, 4 females) of 56 age 1 and 59 (35 males and 24 females) of 65 age 2 individuals collected at Nutria-Tampico between 6 April and 2 June 1995 (4 samples) were mature. On 16 June 1995, 19 (14 males, 5 females) of 29 age 1 fish and all age 2 individuals (n = 14) at Tampico-Nutria were mature.

Length-mass relationships of 5 populations sampled in July 1994 indicated near-isometric growth (Fig. 4b). With SL the covariate, length-mass relationships of these populations did not differ ($F_{4,335}$ = 1.95, P = 0.10). However, with-

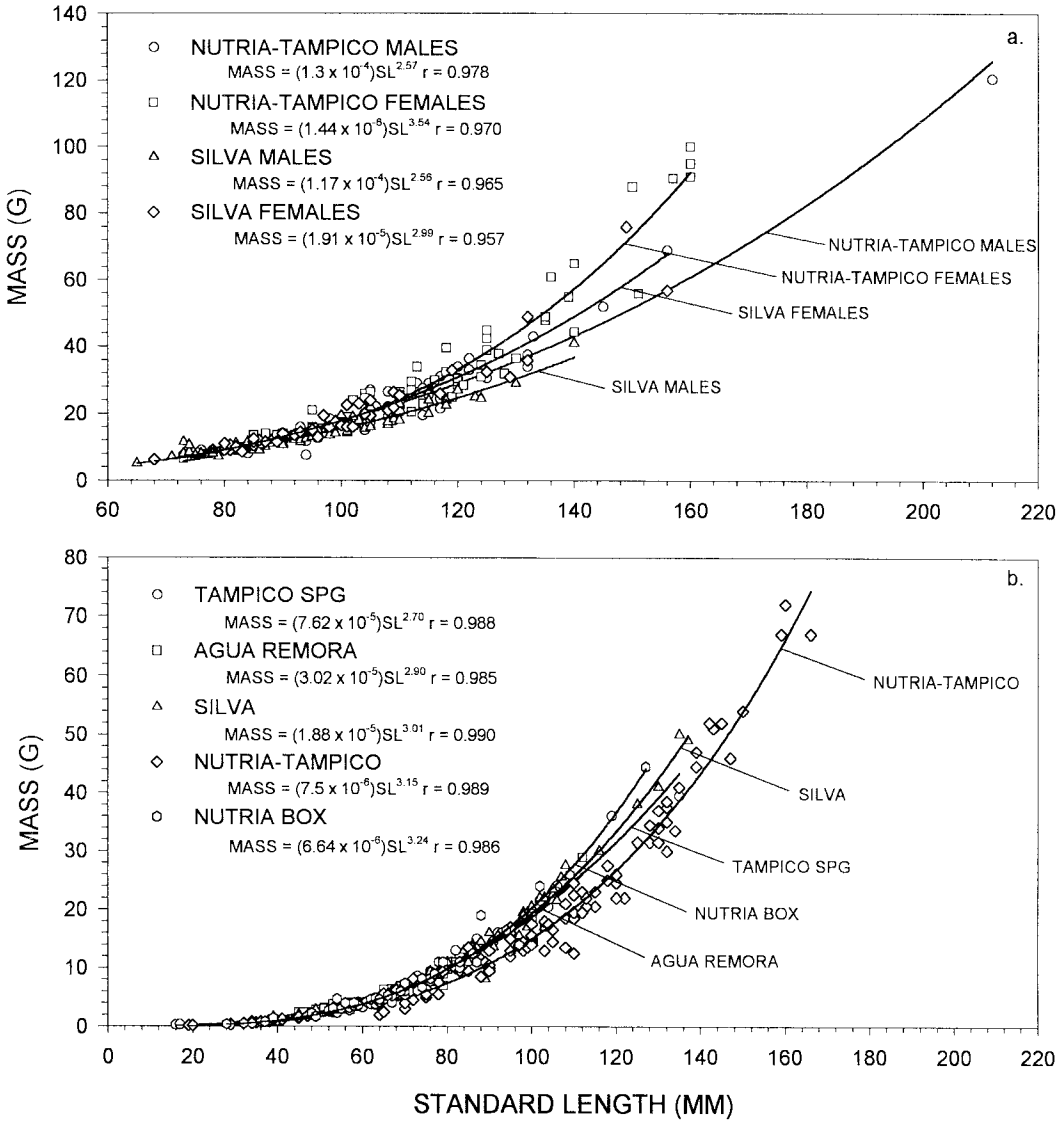

FIG. 4—Length-mass relationships of male and female Zuni bluehead sucker at: a) Nutria-Tampico and Silva during 5 April through 16 June 1995, and b) at 5 sites, sexes combined, in July 1994.

out SL as covariate, differences among populations were found ($F_{4,336}$ = 7.19, P < 0.001). Post hoc tests indicated that mean mass of Agua Remora and Nutria Box fish was significantly less than Silva (P = 0.009 and 0.001, respectively) and Nutria-Tampico (P = 0.001 and 0.002, respectively).

Mean relative condition for most length-classes of each population sampled in July 1994 was between 1.6 and 2.2 (Fig. 6). Mean relative condition for Nutria-Tampico (K = 1.67) was lowest, and Tampico Spring was highest (K = 2.05) of the 5 populations; differences among populations were significant ($F_{4,70}$ = 4.04, P = 0.005). Post hoc tests indicated relative condition of Nutria-Tampico was significantly less than Tampico Spring (P = 0.007), Silva (P = 0.035), and Nutria Box (P = 0.012).

DISCUSSION—Fragmented distribution of Zuni bluehead sucker in headwater and mainstem habitats of upper Río Nutria is a conse-

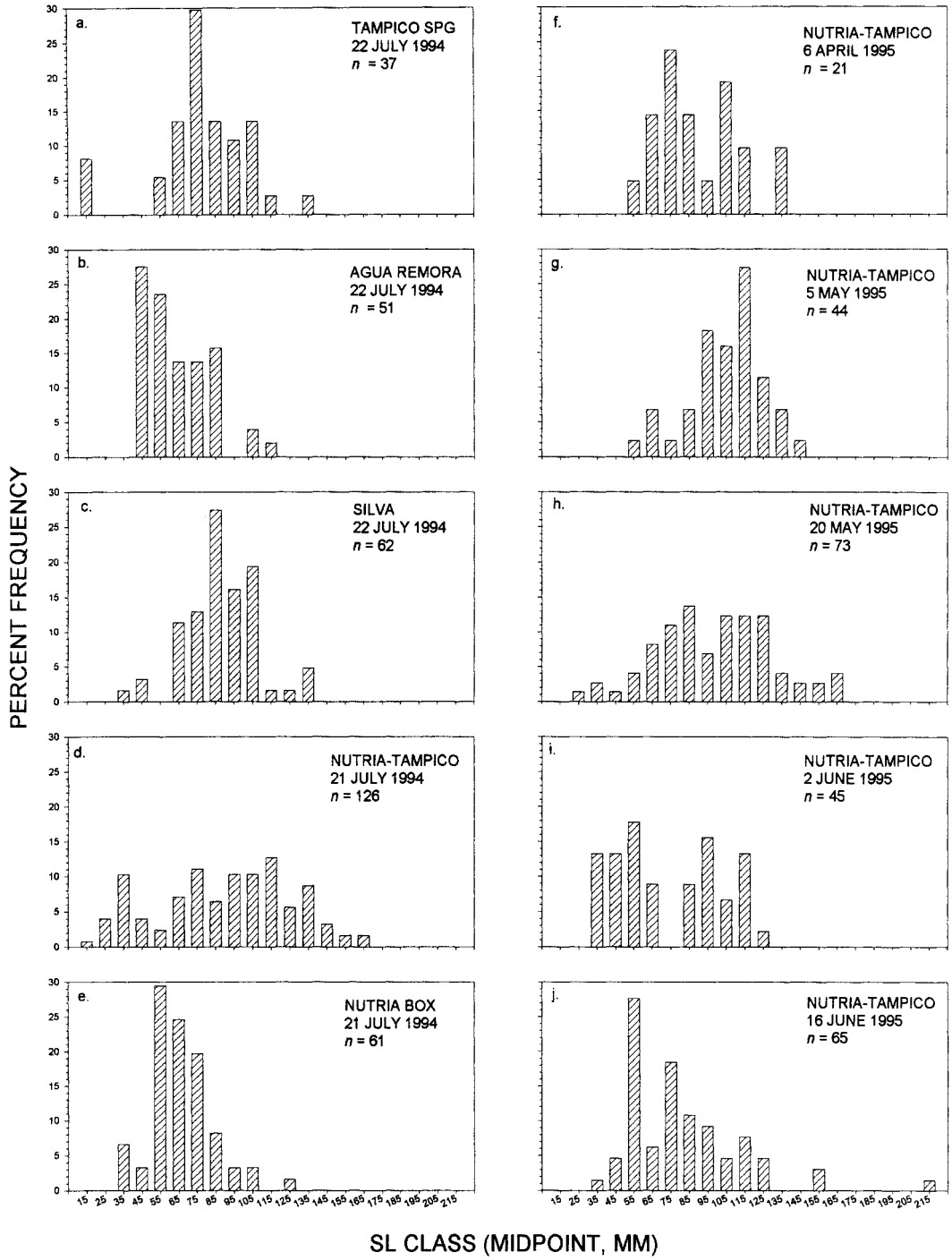

FIG. 5—Length-frequency of Zuni bluehead sucker at 5 sites (a through e) in July 1994, and its length-frequency at Nutria-Tampico (f through j) during the reproductive season, 5 April through 16 June 1995.

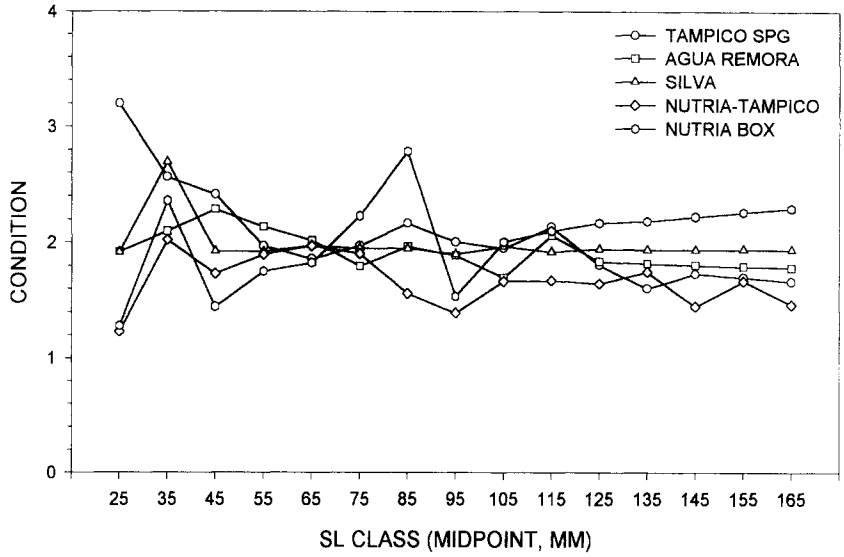

FIG. 6—Mean relative condition ($K = mass/SL^3 \times 10^5$) of Zuni bluehead sucker in July 1994 at 5 locations in the upper Río Nutria drainage, New Mexico.

quence of climate, local geology and hydrology, past land-use practices, resource management activities, and life-history strategies of the fish. It persists mainly in small, semi-isolated populations in upper Río Nutria (upstream from Nutria Canyon mouth) and its headwaters; together, these reaches provide less than 15 km of habitat. It no longer occurs in Zuni River and only incidentally in Río Pescado and lower Río Nutria, a range reduction of about 90% in New Mexico. Individuals from extant populations may disperse downstream or among upstream reaches during periods of elevated discharge, but dry reaches and low waterfalls limit movements during baseflow periods.

Swift-Miller et al. (1999*a*) reported that abundance and condition of Rio Grande sucker (*Catostomus plebeius*) was negatively related to amount of fine sediment. Although we did not quantify the relationship, Zuni bluehead sucker was absent or uncommon where substrate was mainly silt and sand. Downstream from the mouth of Nutria Canyon, habitats are primarily deep, low-velocity, silt- and sand-bottomed pools. Presence of predatory, nonnative fish species, particularly green sunfish, may additionally limit distribution of Zuni bluehead sucker.

Spawning began in spring when water temperature was about 6°C and evidently peaked at about 10°C. Reproduction lasted about 6 weeks, from early April to early June. By mid-June few females had ova, and no July specimen indicated spawning potential. In the Rio de las Vacas of northern New Mexico, spawning by Rio Grande sucker was in June 1985 and 1987 during spring runoff recession (water temperature not reported; Rinne, 1995). Maddux and Kepner (1988) observed bluehead sucker spawning on 2 May 1985 in Kanab Creek, Arizona, when water temperature varied from 18.2 to 24.6°C. We did not sample in autumn, but autumn spawning by Rio Grande sucker was observed by Koster (1957), and Swift-Miller et al. (1999*b*) collected Rio Grande sucker males emitting milt, but no ripe females in November 1994 in Hot Creek, Colorado.

Patterns of occurrence of mature ova and GSI values suggested bimodal spawning by Zuni bluehead sucker at Nutria-Tampico. There, most reproduction likely occurred in a first session when 7 of 11 females had mature ova; only 3 of 8 had mature ova during a presumed second session. Rinne (1995) alluded to bimodal spawning by Rio Grande sucker in northern New Mexico, but provided no details. Most Zuni bluehead sucker females produced 400 to 600 mature ova per year, but large (>140 mm SL) individuals may have 800 or more. Several females ($n = 5$) had <100 mature ova. In contrast, Rinne (1995) reported a

mean of 2,035 mature ova from Rio Grande sucker females >100 mm TL, and McAda and Wydoski (1983) found 5,000 to 8,500 in females (>300 mm TL) of bluehead sucker. Rinne (1995) estimated that Rio Grande suckers are mature at 90 mm TL, about the same size that we found (70 to 90 mm SL) for the majority of Zuni bluehead sucker. Male Zuni bluehead suckers were more common than females; its ratio (1.5:1.0) was greater than that reported for Rio Grande sucker (1.1:1.0) by Rinne (1995). Based on length-frequency distribution, age 0 through age 3 fish were present at Nutria-Tampico in July 1994, and percent in each putative age-class was roughly similar. Without corroborative methods (age estimation from scale or otolith annuli), however, our age estimates are tentative. We estimated that individuals may reach 50 mm SL by July of their first year and subsequently grow about 30 to 40 mm/year. Swift-Miller et al. (1999*b*) reported similar growth of about 30 mm for a cohort of Rio Grande sucker (age not determined) from June through autumn (September, October, November samples combined) in Hot Creek, Colorado.

We found differences among populations of Zuni bluehead sucker in several somatic attributes and similarities in others. During the 1995 reproductive season, size (determined by SL) of males and females at Nutria-Tampico was greater than those at Silva. In July 1994, size-range of suckers was greater at Nutria-Tampico (19 to 166 mm SL) than 4 other sites, but mean relative condition of Nutria-Tampico suckers was least (1.67 versus 1.93 to 2.06). Overall, length-mass relationships in July 1994 were similar, but suckers at Nutria-Tampico gained less mass per unit increase in SL than other populations. Four age classes were present at Nutria-Tampico, whereas the large majority of suckers at other sites were in 1 or 2 age-classes (probably age 1 and 2). Inter-population differences may simply reflect overall variation among semi-isolated populations (i.e., statistical versus biological differences) or were perhaps related to unquantified differences in habitat dimensions and quality.

Reduction of range to ca. 15 km of Río Nutria headwaters, limited connectivity among remnant populations, and restriction of each to short permanently-watered reaches (≤2 km) make persistence of Zuni bluehead sucker tenuous. Natural events (e.g., drought or scouring floods), land-use practices causing elevated sediment deposition, or introduction of piscivorous nonnative fish species could eliminate any remnant population. The Río Nutria headwaters is a checkerboard of private (including The Nature Conservancy), tribal, and federal lands. Conservation of the taxon will require increased coordination and cooperation among these entities, and other resource managers. Although additional information on biology, population dynamics, and habitat requirements are essential, the most pressing need for conservation of Zuni bluehead sucker is implementation of strategies to protect and enhance extant populations.

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