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Observations on habitat use of age-0 Rio Grande Blue Sucker (*Cycleptus* sp. cf. *elongatus*)

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Abstract.—During April 2018, we collected 23 age-0 (33–55 mm total length) Rio Grande Blue Sucker (*Cycleptus* sp. cf. *elongatus*) from 3 locations in the Rio Grande near the confluence with the Rio Conchos where the species is rarely reported. Age-0 Rio Grande Blue Suckers occurred in habitats ranging from 6 to 81 cm deep, with current velocities ranging from 0 to 1.03 m/s over silt, sand, gravel, cobble, and bedrock substrates. There was limited evidence for greater detection in slower-velocity habitats with bedrock, silt, and sand substrates, but the habitats we sampled were not unique from habitats sampled in a previous year-round study reporting only a single individual. We conclude that our sampling occurred shortly after successful recruitment, and that age-0 Rio Grande Blue Suckers use a wide variety of habitats.

Resumen.—Durante abril del 2018, recolectamos en 3 sitios del Río Grande (Río Bravo) 23 matalotes azules (*Cycleptus* sp. cf. *elongatus*) de 0 años (de 33 a 55 mm de longitud total), cerca de la confluencia con el Río Conchos, donde en escasas ocasiones se ha reportado esta especie. Los matalotes azules de 0 años fueron encontrados en hábitats de 6 a 81 cm de profundidad, con corrientes cuya velocidad oscila entre 0 a 1.03 m/s sobre sustratos de limo, arena, grava, guijarro y roca madre. Encontramos poca evidencia de la presencia de malotes azules en hábitats con corrientes de menor velocidad con sustratos de roca madre, limo y arena. Sin embargo, los hábitats que muestreamos no fueron los únicos (resultados provenientes de estudios de un año anterior) donde se registró un único individuo. Concluimos que nuestro muestreo ocurrió después de un reclutamiento exitoso y que los matalotes azules de 0 años se distribuyen en una amplia variedad de hábitats.

Fish assemblages in the American Southwest and Rio Grande Basin have suffered declines, extirpations, and extinctions due to anthropogenic change that began as early as the 1800s (Miller 1961, Burkhead 2012). Most of the changes to the assemblage and species abundances are irreversible; over half of the endemic species of the region have a status of at least "threatened"; and very few ecosystems and faunas are left intact (Hubbs 1990, Edwards et al. 2002). Although these losses have significantly and perhaps irreversibly impacted the composition of biodiversity in the Rio Grande, there is considerable remaining diversity that is currently poorly documented (e.g., Pinion et al. 2018). One example is the currently undescribed Rio Grande Blue Sucker (*Cycleptus* sp. cf. *elongatus;* Burr and Mayden 1999, Buth and Mayden 2001), a species listed as "threatened" by the American Fisheries Society (Jelks et al. 2008) and a "species of special concern" by the state of Texas (Hubbs et al. 2008). Despite this unnerving conservation status, relatively little is known regarding distribution and life history of the Rio Grande Blue Sucker.

During 16–17 April 2018, we collected 23 age-0 Rio Grande Blue Sucker from 3 locations on the mainstem Rio Grande near the Rio Conchos. Four individuals were collected at the Balanced Rock Trail in Big Bend Ranch State Park (29.35373° N, 104.090097° W), 15 at the mouth of Contrabando Creek (29.27907° N, 103.84215° W), and 4 at Lajitas Old Crossing (29.26429° N, 103.78293° W). Previous surveys over a 40-year period conducted on the Rio Grande between the Rio Conchos confluence and Big Bend National

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TABLE 1. Candidate occupancy models developed to quantify seining detection probability for Rio Grande Blue Sucker (*Cycleptus* sp. cf. *elongatus*) in the Rio Grande. Ψ is occupancy probability and was assumed constant (.); *p* is detection probability; vel is water velocity (m/s); dep is depth (m); sub is substrate class (see text); K is the number of model parameters; QAICc is quasi Akaike information criterion; ΔQAIC is the difference between the top-ranked model and all other models; QAICcWt is the conditional probability that each model is the top-ranked model; CumWt is the cumulative weight across models; and QuasiLL is the quasi log-likelihood.

Model	K	QAICc	ΔQAICc	QAICcWt	CumWt	QuasiLL
Ψ(.), *p*(.)	3	4.49	0	0.27	0.27	−11.25
Ψ(.), *p*(vel + vel^2 + dep + dep^2 + sub)	12	5.19	0.69	0.19	0.45	−6.19
Ψ(.), *p*(vel + vel^2 + sub)	10	5.48	0.98	0.16	0.62	−6.49
Ψ(.), *p*(sub)	8	7.17	2.68	0.07	0.69	−7.59
Ψ(.), *p*(dep + sub)	9	7.28	2.79	0.07	0.75	−7.5
Ψ(.), *p*(vel + sub)	9	7.33	2.84	0.06	0.82	−7.52
Ψ(.), *p*(vel + dep + sub)	10	7.34	2.85	0.06	0.88	−7.42
Ψ(.), *p*(dep + dep^2 + sub)	10	7.36	2.86	0.06	0.95	−7.43
Ψ(.), *p*(dep)	4	10.24	5.75	0.02	0.96	−11.12
Ψ(.), *p*(vel)	4	10.49	6	0.01	0.97	−11.25
Ψ(.), *p*(vel + vel^2)	5	11.19	6.7	0.01	0.98	−10.6
Ψ(.), *p*(vel + vel^2 + dep + dep^2)	7	12.14	7.65	0.01	0.99	−10.27
Ψ(.), *p*(dep + dep^2)	5	12.23	7.73	0.01	0.99	−11.11
Ψ(.), *p*(vel + dep)	5	12.23	7.74	0.01	1	−11.12

Park reported 0 (Hubbs et al. 1977), 0 (Bestgen and Platania 1988), 0 (Edwards et al. 2002), 1 (Heard et al. 2012), and 1 (Edwards 2013) Rio Grande Blue Sucker. By comparison with these previous studies, we found the species to be relatively abundant (i.e., 7% relative abundance; 2.5 fish/100 m^2). Rare reports of the species in previous collections could be caused by either absence from the reach or presence that went undetected. Alternatively, habitats might have shifted in the time between previous works and our collections, resulting in detection within new and unique habitats. Given the paucity of information on the Rio Grande Blue Sucker, we tested 2 hypotheses using our limited but novel data set. We first hypothesized that detection efficiency would be related to substrate, current velocity, and water depth, such that detection would be greatest over finer substrates in slower, shallower water, where seines can more easily be pulled. Second, we hypothesized that the habitats we sampled were unique among those previously surveyed and were more conducive to collecting age-0 Rio Grande Blue Sucker.

Our quantitative sampling was based on the protocols described by Heard et al. (2012). At each site, we conducted twenty 5-m-long hauls with a seine (3 × 1.8 m, 3.1-mm mesh size) within discrete habitat, measured water depth (m) and current velocity (m/s) in 2 places, and classified the dominant substrate using a modification of the scale of Wentworth (1922). Our substrate classifications included silt (<0.06 mm diameter), sand (0.06–2 mm), gravel (2–32 mm), cobble (32–256 mm), boulder (>256 mm), or bedrock (solid substrate). We identified all species collected and released individuals before we moved at least 10 m for the next seine haul to avoid replicated catches from previous hauls (Albanese et al. 2014). Species captured with Rio Grande Blue Sucker included Red Shiner (*Cyprinella lutrensis*), Conchos Shiner (*C. panarcys*), Speckled Chub (*Macrhybopsis aestivalis*), Tamaulipas Shiner (*Notropis braytoni*), Longnose Dace (*Rhinichthys cataractae*), River Carpsucker (*Carpiodes carpio*), and Western Mosquitofish (*Gambusia affinis*).

We tested our first hypothesis regarding detection using spatially replicated visits and fit the single-season occupancy model of MacKenzie et al. (2002). The use of spatial rather than temporal replication to estimate capture efficiencies is a commonly applied method for assessing detectability of imperiled stream fishes (Albanese et al. 2014, Shea et al. 2015, Mollenhauer et al. 2018, but see Kendall and White 2009). We developed capture histories across the 20 seine hauls conducted at each site and used mean depth, mean velocity, and substrate classes as detection covariates. We assumed constant site occupancy for the analysis (Albanese et al. 2014) and modeled detection probability using the following equation:

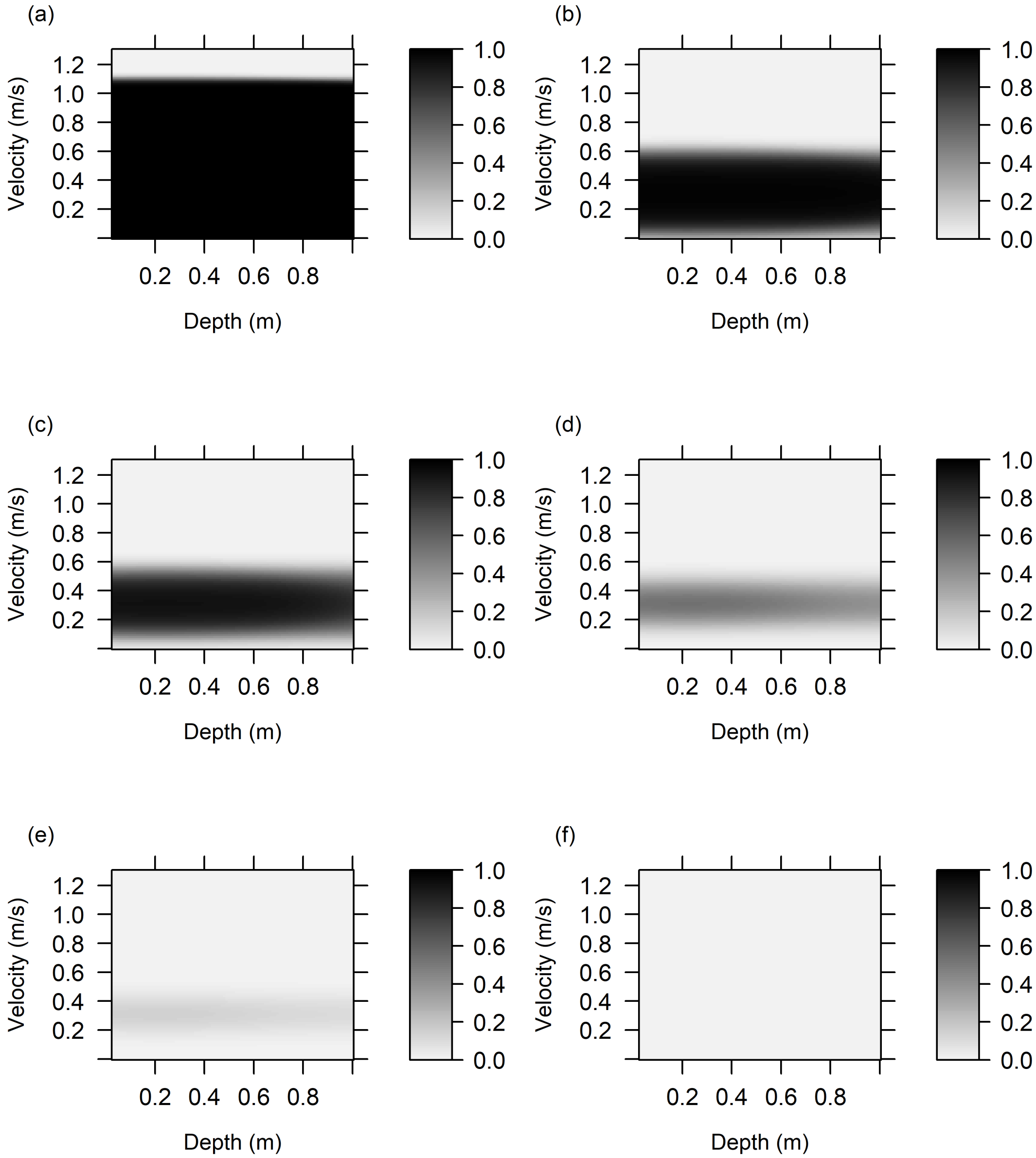

Fig. 1. Detection probability (range 0–1) for age-0 Rio Grande Blue Sucker (*Cycleptus* sp. cf. *elongatus*) as a function of depth (m) and velocity (m/s) for habitats with 6 substrate classes: (a) bedrock, (b) silt, (c) sand, (d) gravel, (e) cobble, and (f) boulder.

$$\text{logit}(P_{ij}) = v_{ij}^{\mathrm{T}}\alpha$$

where P is detection probability for seine haul i at site j, v is a vector of detection covariates, and α represents the coefficients for v. We developed 14 candidate models using depth (including a quadratic term), velocity (including a quadratic term), substrate, combinations of these terms, and an empty model (no covariates). We included both depth and velocity because there was no relationship between the 2 variables (Pearson's $r = 0.07$). We used the goodness-of-fit test described by MacKenzie and Bailey (2004) on the most complex model to test for overdispersion using 1000 bootstraps (Mollenhauer et al.

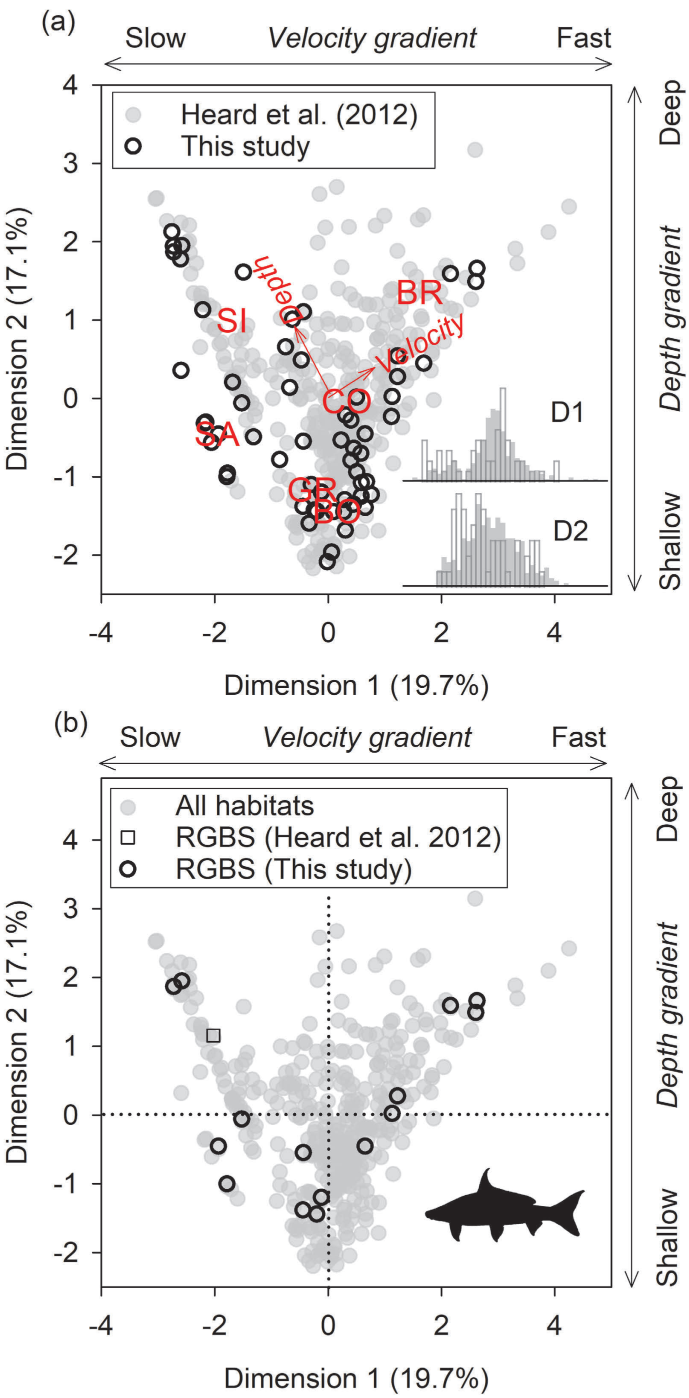

Fig. 2. (a) Multiple factor analysis illustrating habitats sampled during previous surveys by Heard et al. (2012) (light gray, closed circles) and this study (black, open circles). Each point is a seine haul collected along continuous velocity and depth gradients and over substrates that included silt (SI), sand (SA), gravel (GR), cobble (CO), boulder (BO), and bedrock (BR). Inserts show high overlap in sampled habitats by Heard et al. (2012) (gray bars) and this study (open bars) along dimension 1 (D1) and dimension 2 (D2). (b) Multiple factor analysis illustrating the seine hauls in which Rio Grande Blue Sucker (RGBS) was collected in the current study (black, open circles) and in the study by Heard et al. (2012) (a single specimen; black, open box).

2018). Because overdispersion was evident ($\hat{c}$ = 3), we ranked candidate models using the quasi-Akaike information criterion adjusted for small sample size (QAICc; Burnham and Anderson 2002). We fit models using the *occu* function from R package *unmarked* (Fiske and Chandler 2011), adjusted for overdispersion, and built competing models using the *aictab* function from the package *AICcmodavg* (Mazerolle 2017). The top model included no covariates for detection, but 2 competing models (QAICc < 2) included quadratic velocity, quadratic depth, or substrate (Table 1). We averaged the top 3 models and found that detection probability was greatest for velocities of 0.1–0.3 m/s and over bedrock, silt, and sand substrates (Fig. 1).

We tested our second hypothesis regarding the uniqueness of habitats sampled in 2018 using data collected by Heard et al. (2012). Sampling by Heard and coauthors was much more extensive than our April 2018 sampling, including a minimum of 20 seine hauls conducted at the mouth of Contrabando Creek once a month for 12 months during 2006. This previous work provided a good picture of the temporal dynamics of habitats in the mainstem Rio Grande within our study segment. We ordinated seine haul habitat data (n = 348 hauls) collected by Heard et al. (2012) along with our data (n = 60 hauls) to compare multivariate habitat distributions using multiple factor analysis (Escofier and Pagès 1994). Multiple factor analysis (MFA) allowed for summarizing mixed classes of data, including continuous variables (depth, velocity) and categorical classes (substrate classifications), into a single plot so that habitat gradients from the 2 time periods could be directly compared. The first 2 MFA dimensions explained 36.5% of variation in sampled habitats and illustrated that habitats sampled in 2018 were not unique from those sampled in 2006 (Fig. 2a). Kolmogorov–Smirnov tests (Massey 1951; $\alpha = 0.05$) showed no differences in habitat distributions between 2006 and 2018 along dimension 1 ($D = 0.17$, $D_{crit} = 0.21$) or dimension 2 ($D = 0.18$, $D_{crit} = 0.21$). The diversity of habitats used by age-0 Rio Grande Blue Sucker was evident when the seine hauls that included the species were highlighted (Fig. 2b). We collected age-0 Rio Grande Blue Sucker over silt, sand, gravel, cobble, and bedrock substrates and in the following habitats: (1) slow deep habitats (velocity 0–0.09 m/s, depth 80–81 cm), (2) slow intermediate-depth habitats (velocity 0–0.35 m/s, depth 15–48 cm), (3) fast intermediate-depth habitats (velocity 0.83–1.03 m/s, depth 22–31 cm), and (4) one relatively fast and shallow habitat (velocity 0.39 m/s, depth 0.6 m). The single Rio Grande Blue Sucker collected by Heard et al. (2012) at the mouth of Contrabando Creek in April 2006 was collected from a slow and deep habitat (velocity 0.10 m/s, depth 0.53 m).

This report adds to our limited knowledge of the ecology of Rio Grande Blue Sucker. Based on their collection of 20–40 mm TL individuals in Tornillo Creek during April and May 1972, Hubbs and Wauer (1973) concluded that Rio Grande Blue Suckers likely spawn during March or April. The timing of collections and size of specimens we observed support the spawning season identified by Hubbs and Wauer (1973) and suggest stronger recruitment in 2018 compared to 2006. The observed differences in the number of Rio Grande Blue Sucker collected in our study versus the previous 40-year period could be related to long-term changes in climate, water quantity, water quality, or channel geomorphology (Edwards and Contreras-Balderas 1991, Dean and Schmidt 2011, Taylor et al. 2019), but additional research is required to uncover any such mechanism. Cowley and Sublette (1987) found that adult Rio Grande Blue Sucker inhabited only deep pools with silty substrate in the Black River of New Mexico, but Koster (1957) suggested that specimens of unreported size occupied only swift riffles in the Lower Pecos River. We found that age-0 individuals in the mainstem Rio Grande used all of these previously documented habitats. Finally, collections of juveniles of the closely related but widely distributed Blue Sucker (*Cycleptus elongatus*) are rare across the range of that species (Moss et al. 1983, Adams et al. 2006, Eitzmann et al. 2007), and the same is true for Rio Grande Blue Sucker. Our findings provide new insight into the diversity of habitats used by early life stages of Rio Grande Blue Sucker.

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