NM WRRI Student Water Research Grant Progress Report Form

Progress Report due Friday October 1, 2021
Draft Final Report due Friday, April 22, 2022
Final Report due Thursday May 19, 2022

1. Student Researcher: Laramie Mahan; Eastern New Mexico University
Faculty Advisor: Dr. Ivana Mali; Eastern New Mexico University

2. Project title:
Occupancy and detection of Rio Grande cooter (*Pseudemys gorzugi*) on the Pecos River

3. Research problem and objectives:
The Rio Grande cooter (*Pseudemys gorzugi*) is a little studied freshwater turtle that is native to the Rio Grande and Pecos River drainages in southeastern New Mexico, southwestern Texas, and northeastern Mexico. The species is currently listed as threatened in New Mexico and Mexico and is a species of greatest conservation need in Texas. Additionally, the species was previously under review by the United States Fish and Wildlife Service (USFWS) for potential federal protection under the Endangered Species Act with a decision made not to list in March of 2022 (Pierce et al. 2016; Endangered and Threatened Wildlife and Plants 2022). In recent years, the species has been primarily studied on tributaries of the Pecos River in New Mexico and Texas, including the Black and Devils River, respectively. However, the Pecos River itself has not been consistently surveyed for turtles in over a decade. The Pecos River is one of the most anthropogenically altered river systems, originating in northeastern New Mexico, flowing southward through the southeastern portion of the state and west Texas, where it meets the Rio Grande at the Mexico-USA border. The lower portion of the Pecos River contains naturally saline groundwater due to upwellings of underground brine and Halite salt crystal formations. Since the late 1800s, factors including urbanization, channelization, reduced stream flow, increased evapotranspiration, and reduced flood frequency have allowed certain areas of the Pecos River to become susceptible to excess salt buildup, and declines in water availability and quality (Hoagstrom 2009). The objective of this study was to (1) determine the current distribution of the *P. gorzugi* throughout its assumed range along the lower Pecos River; (2) determine which environmental and habitat characteristics contribute to the presence or absence of the species by utilizing a single-season, single-species occupancy modeling framework. In doing so, I collected data on water quality parameters, daily atmospheric conditions, and surrounding landscape that was hypothesized to have an impact on the occurrence and detection of *P. gorzugi*.

4. Methodology:
I conducted freshwater turtle surveys across 32 survey sites of the Pecos River in the summer months (May-August) of 2020 and 2021, with 16 sites surveyed each year. Each site was visited for three survey occasions within the season, with 45 hoop-net traps placed in the water for 48 hours. Specific trapping localities are not included in this report due to conservation concerns and the privacy of private landowners. Each turtle captured was identified, measured, marked, and released. Parameters that were hypothesized to influence the occupancy and detectability of *P. gorzugi* were recorded. Water quality parameters recorded included pH, conductivity (µS/cm), nitrates (mg/L), dissolved oxygen (mg/L), and temperature (°C). River characteristics including flow (m/s), water visibility (turbidity; m),

depth (m), width (m), surface area (m^2), aquatic vegetation, presence of basking structures, and landscape condition were also recorded and/or analyzed. Conductivity and pH were recorded once per site, per survey occasion. Conductivity was recorded as a proxy for salinity, as conductance refers to the water's ability to produce an electrical current through ions (e.g., dissolved salts on the Pecos River). Due to probe availability and limited access to the previous year's sites (e.g., flood damage to roads), nitrates and dissolved oxygen were recorded once per site, per survey occasion for the summer of 2021. Missing values were estimated for 2020 sites by using the closest proximal 2021 site nitrate and dissolved oxygen values, or the mean values between two sites of similar distance (minimum and maximum distances between sites ~3 river km and ~94 river km, respectively). Conductivity, pH, nitrates, and dissolved oxygen were measured using YSI Pro Plus Multiparameter instruments (YSI Incorporated, Yellow Springs, OH). Temperature was recorded every four hours for 48 hours using HOBO Pendant® MX Temperature/Light Data Loggers (ONSET, Bourne, MA). There were malfunctions of the HOBO loggers at six of the sites, for one survey occasion each. To accommodate missing temperature values, I created linear regression equations using recorded temperatures of other survey occasions at the same site of interest, and the corresponding air temperatures from the nearest approximate time and location of survey. Air temperatures were accessed from timeanddate.com. Flow, depth, and turbidity were recorded three times per site, per survey occasion at the first, middle, and last traps, respectively. Flow in Texas was measured by inserting an OTT MF pro meter (OTT HydroMet, Germany) and recording the minimum and maximum flow for 15 seconds. Flow in New Mexico was measured by inserting a Flowatch® Flowmeter (JDC Instruments, Switzerland) into the river and recording the maximum flow after 15 seconds. Depth was measured by submerging a 10-pound dumbbell weight fixated with a nylon rope marked every 0.5 m. Water visibility was measured by submerging a Secchi disk and recording the depth at which visibility was lost and regained. For each survey occasion, surface area was calculated in Google Earth using the polygon tool and the GPS coordinates of traps as references. Width was calculated by creating 15 evenly spaced lines within each surface area polygon and recording the mean value. Mean landscape condition of each site was calculated using the NatureServe Landscape Condition Model (LCM). The LCM utilizes spatial data from LANDFIRE, National Land Cover Data, and USGS ReGap data in the USA to rank the landscape (from 0 [poor] to 1 [excellent]) as a metric of ecological integrity (Hak and Comer 2017). I created 100 m buffers around each surface area polygon in ArcMap and calculated the mean landscape condition within each buffer. Vegetation was documented categorically, based on the presence/absence of aquatic vegetation (cattails [*Typha* sp.] and giant reed [*Arundo donax*]).

I utilized a single-season, single-species occupancy modeling framework to estimate the detection and occupancy probabilities for *P. gorzugi*, using replicate detection/non-detection data as a response variable. I used site-specific covariates (i.e., covariates that remain relatively unchanged throughout each survey occasion) assuming they are representative of long-term habitat conditions: mean pH, mean conductivity, nitrates, dissolved oxygen, mean water visibility, maximum depth, maximum flow, vegetation (0 = no aquatic vegetation, 1 = aquatic vegetation), presence/absence of basking structures (i.e., fallen logs), and mean landscape condition (Table 1). Survey-specific covariates that could vary across survey occasions included day of year (using Julian Date system), observable atmospheric conditions (cloudy vs. sunny), visual presence/absence of any turtles (proxy for turtle activity), water temperature, surface area, and water visibility at time of survey (Table 1). Using the data collected from 32 survey sites, I fit occupancy models using the "unmarked" package in R (Fiske and Chandler 2011). Prior to fitting the models, continuous covariates were standardized to have a mean of zero and standard deviation of one. Covariates were also checked for collinearity using Pearson's correlation coefficient. Two covariates (pH and nitrates) were excluded as they were highly correlated with other parameters of interest ($|r| > 0.7$). I then constructed the models using a sequential-by-submodel strategy. I first compared all possible model combinations for detection while holding occupancy constant. Detection models were compared using Akaike Information Criterion values corrected for small sample size (AICc; Burnham and Anderson 1998). Top models were moved forward if they had a Δ AIC < 5 and contained no uninformative parameters (Arnold 2010). Then, using the top detection models I ran all possible model combinations for occupancy, while removing any combination of covariates that resulted in model convergence issues. The final model set was again limited to those with a Δ AIC < 5 and no uninformative parameters. Odds ratio was then used to interpret effects of top covariates, as the effect sizes will remain constant across changes in predictor variables (i.e., covariates; Hosmer et al. 2013).

5. Results:
   Of the recorded parameters, conductivity varied the most, with a range of 1424–37397 µS/cm (Table 1), with levels gradually increasing from upstream-most sites to downstream (Fig. 1), and lower conductivity levels near spring-fed tributaries. Five species of turtles were captured during surveys: Red-eared slider (*Trachemys scripta elegans*), Spiny softshell turtle (*Apalone spinifera emoryi*), Yellow mud turtle (*Kinosternon flavescens*), Common snapping turtle (*Chelydra serpentina*), and *P. gorzugi*. Observed species richness ranged from 0–5 per site, with generalist species *T. s. elegans* and *A. s. emoryi* most abundant (Fig. 2). No turtles of any species were captured at the five sites with the highest conductivity levels. A total of 60 unique *P. gorzugi* were captured at 14 of the 32 survey sites, producing a naïve occupancy of 43.75%. Of the captures, 38 were males, 20 were females (2:1 male to female ratio) and only 2 were juveniles (Fig. 3).

   Of the detection models, four had a Δ AIC < 5 and contained no uninformative parameters (Table 2). Of the top models for detection and occupancy, two had a Δ AIC < 5 and no uninformative parameters (Table 2). Based on the best fit model (Table 3), detection is most influenced by water visibility (i.e., turbidity) of the survey site at the time of the survey. Moreover, the odds of detecting *P. gorzugi* was 1.58 times lower for every 0.73 m increase in visibility (Fig. 4). Conductivity significantly influenced occupancy, where the odds of occurrence were 123.97 times lower with every 8719.1 µS/cm increase in conductivity (Fig. 5). The probabilities of occurrence for *P. gorzugi* were higher at sites above the Black River confluence upstream, and near the Independence Creek and Rio Grande Confluences downstream.

6. Occupancy studies can be extremely useful tools in wildlife and aquatic conservation by revealing factors that contribute to the presence or absence of a species of interest and their respective ecosystems. Understanding the environmental and habitat characteristic variables affecting detectability and occurrence may aid in subsequent conservation for the species. This project specifically has shed light on the current distribution of *P. gorzugi* on the Pecos

River as opposed to historical documentation of the species. Moreover, a distributional gap for the species has long been speculated for the Pecos River, and the results herein indicated that there may be a distributional hiatus of ~390 river km due to anthropogenically exacerbated salinization of the river. *Pseudemys gorzugi* may be less tolerant of brackish waters (e.g., detected at sites with conductivity levels > 10,000 µS/cm), as opposed to the more generalist species *T. s. elegans* and *A. s. emoryi* (e.g., detected at sites with conductivity levels up to 20,467 µS/cm). While the species was observed at 43.75% of the survey sites, the estimated proportion of sites occupied by *P. gorzugi* is only slightly higher, at 46.53% (95% CI = 43.75–56.25%). This study indicates that excess salinization was a recent development, and may have adverse affects on the freshwater turtle communities, as even generalist species were not detected in highly saline reaches of the river. Turtles are ecological indicators and are long-lived and slow maturing, thus a decline or absence of historic turtle populations may be a sign of declining habitat health. In New Mexico, agencies including New Mexico Department of Game and Fish, Bureau of Land Management, Carlsbad Soil and Water District, as well as other stakeholders such as farmers, ranchers, etc., could potentially utilize the information provided herein for a greater assessment and understanding of the water quality issues facing the lower Pecos River.

7. The net total of the grant funds was $7342.41. The funds were used to cover portions of my college tuition for the Fall 2021 and Spring 2022 semesters, to purchase the statistical modeling book "Applied Hierarchical Modeling in Ecology: Analysis of Distribution, Abundance and Species Richness in R and BUGS: Volume 2: Dynamic and Advanced Models", and two handheld Garmin GPS's for field surveys.

8. List presentations you have made related to the project.

Mahan, L. B., L. G. Bassett, D. H. Foley, A. Duarte, M. R. J. Forstner, and I. Mali. 2022. Detection and occurrence of Rio Grande Cooter in the lower Pecos River. The AZ/NM TWS/AFS Joint Annual Meeting, Virtual Conference, Feb. 3-5.

Mahan, L. B., L. G. Bassett, A. Duarte, D. H. Foley, M. R. J. Forstner, and I. Mali. 2021. Estimating occurrence and detectability of Rio Grande Cooter (*Pseudemys gorzugi*) on the Pecos River. New Mexico Water Resources Research Institute 66th Annual New Mexico Water Conference, Virtual Conference, Oct. 26-28.

Mahan, L. B., L. G. Bassett, A. Duarte, D. Foley, M. R. J. Forstner, and I. Mali. 2021. Current detectability and occurrence of Rio Grande Cooter on the Pecos River. The Wildlife Society 28th Annual Conference, Virtual Conference, Nov. 1-5.

Mahan, L, B., L.G. Bassett, T. Suriyamongkol, M. R. J. Forstner, and I. Mali. 2021. Freshwater turtle species richness in the Lower Pecos River in New Mexico and Texas. Texas Academy of Sciences Annual Meeting, Virtual Conference, Feb 26-27.

Mahan, L. B., L. G. Bassett, T. Suriyamongkol, M. R. J. Forstner, and I. Mali. 2020. Assessment of freshwater turtle populations on the Pecos River in New Mexico and Texas. New Mexico Academy of Sciences Research Symposium, Virtual Conference, Nov. 9

Mahan, L. B., L. G. Bassett, T. Suriyamongkol, M. R. J. Forstner, and I. Mali. 2020. Naïve occupancy of the Rio Grande Cooter (*Pseudemys gorzugi*) across 16 survey sites on the Pecos River in New Mexico and Texas. New Mexico Water Resources Research Institute 65th Annual New Mexico Water Conference, Virtual Conference, Oct. 26-29.

9. I am currently in the process of writing a manuscript to publish these results.

10. Student Assistants, Eastern New Mexico University: Korry Waldon, Derek Jamerson, Jason R. Bailey, Sierra N. Shoemaker
    Student Assistants, Texas State University: Lawrence G. Bassett, Dalton Neuharth, Devin Preston

11. Notable achievements as a result of research:
    The AZ/NM TWS/AFS Joint Annual Meeting Student Oral Competition, 1st Place Award, 2022.
    The New Mexico Chapter of The Wildlife Society Outstanding Student Award for Excellence in Wildlife Stewardship through Science and Education, 2021.
    New Mexico Academy of Sciences Research Symposium, 1st Place Graduate Poster Award of $100, November 9, 2020.

12. I graduated with a M.Sc. in Biology from Eastern New Mexico University in May of 2022. I now enrolled in a PhD program for Aquatic Resources and Integrative Biology at Texas State University. I aim to continue studying riverine freshwater turtles, and other herpetofauna, focusing on using statistics to help understand species dynamics.

Figures and Graphs

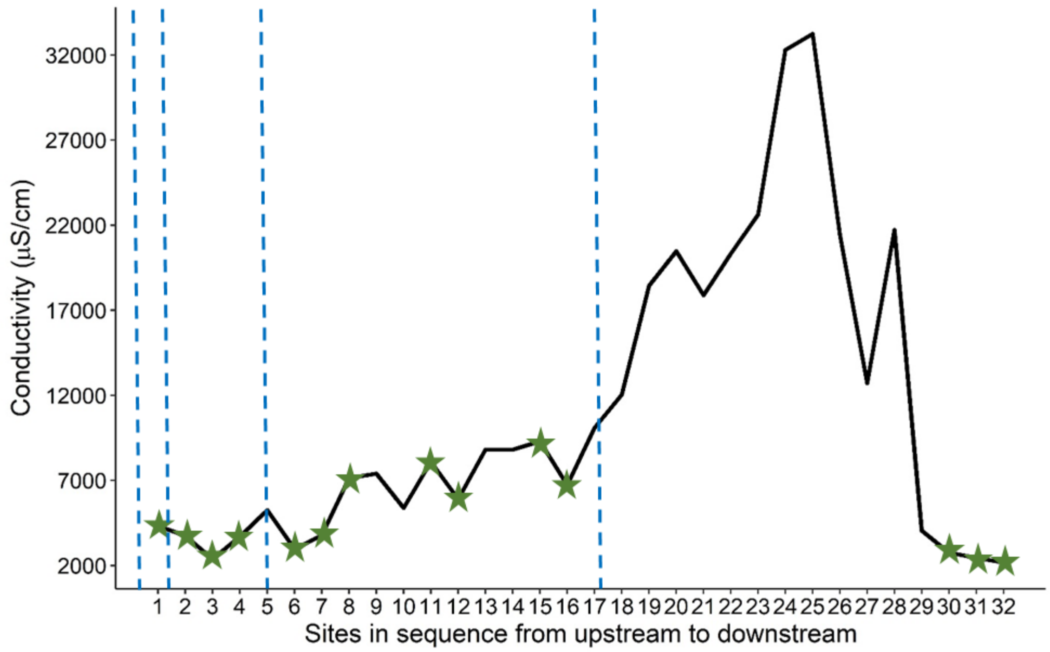

Figure 1. Mean conductivity (µS/cm) levels across 32 survey sites of the lower Pecos River during the summer months of 2020 and 2021. Conductivity levels ranged from 1424–37397 µS/cm. Green stars represent sites where the Rio Grande cooter (*Pseudemys gorzugi*) was detected; blue dashed lines represent dams/reservoirs along the lower Pecos River (Brantley dam, Avalon dam/reservoir, Six-mile dam, and Red-bluff reservoir, respectively).

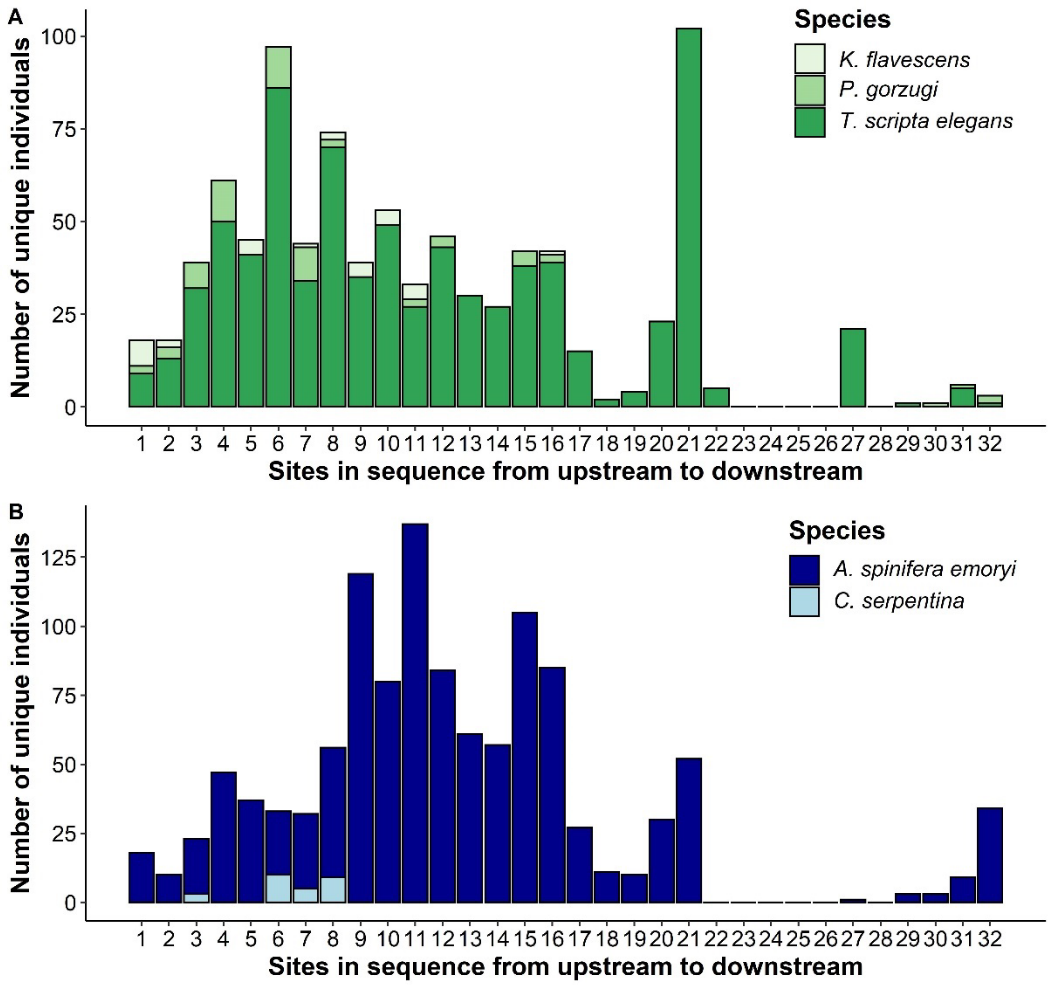

Figure 2. The number of unique captures of five freshwater turtle species in the lower Pecos River, USA during the summer months (May-August) of 2020 and 2021: (A) Total unique captures for Rio Grande cooter (*Pseudemys gorzugi*), Yellow mud turtle (*Kinosternon flavescens*), and Red-eared slider (*Trachemys scripta elegans*); (B) Total number of Spiny softshell turtle (*Apalone spinifera emoryi*) and Common snapping turtle (*Chelydra serpentina*) with recaptures. Due to time constraints and relative abundances of *C. serpentina* and *A. s. emoryi*, ~5–10 representatives of each species were measured and marked, and additional captures were tallied in New Mexico; all *A. s. emoryi* in Texas were measured and marked.

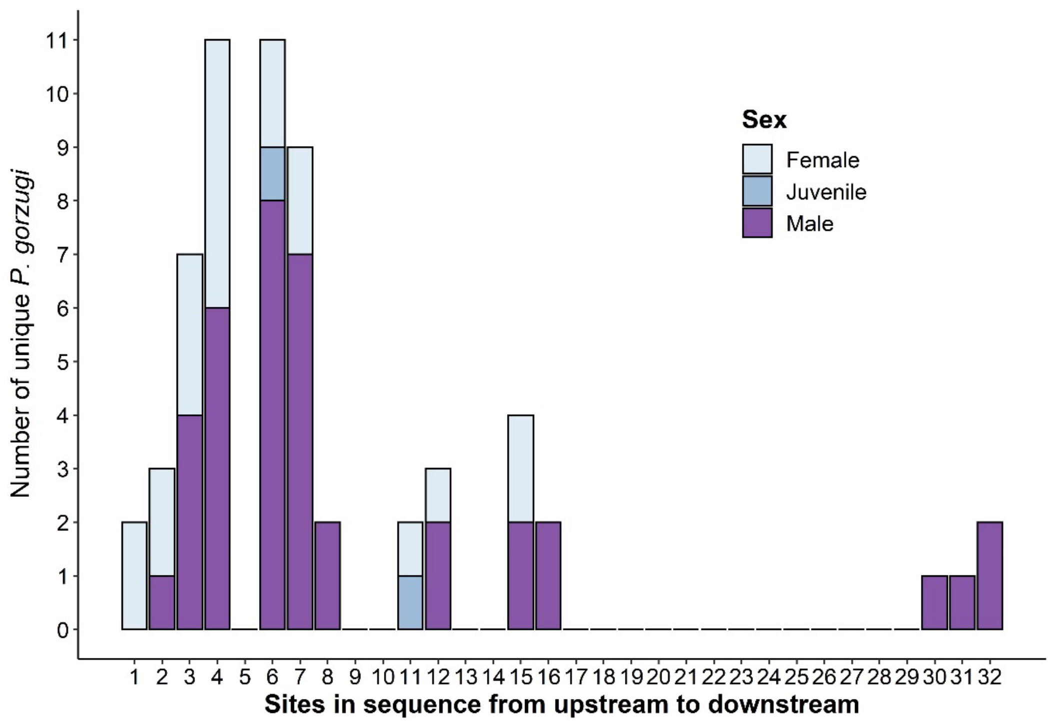

Figure 3. Relative abundances and sex distribution of Rio Grande cooter (*Pseudemys gorzugi*) detected in the lower Pecos River during the summer months (May-August) during 2020 and 2021. A total of 60 unique captures included 38 males, 20 females, and two juveniles.

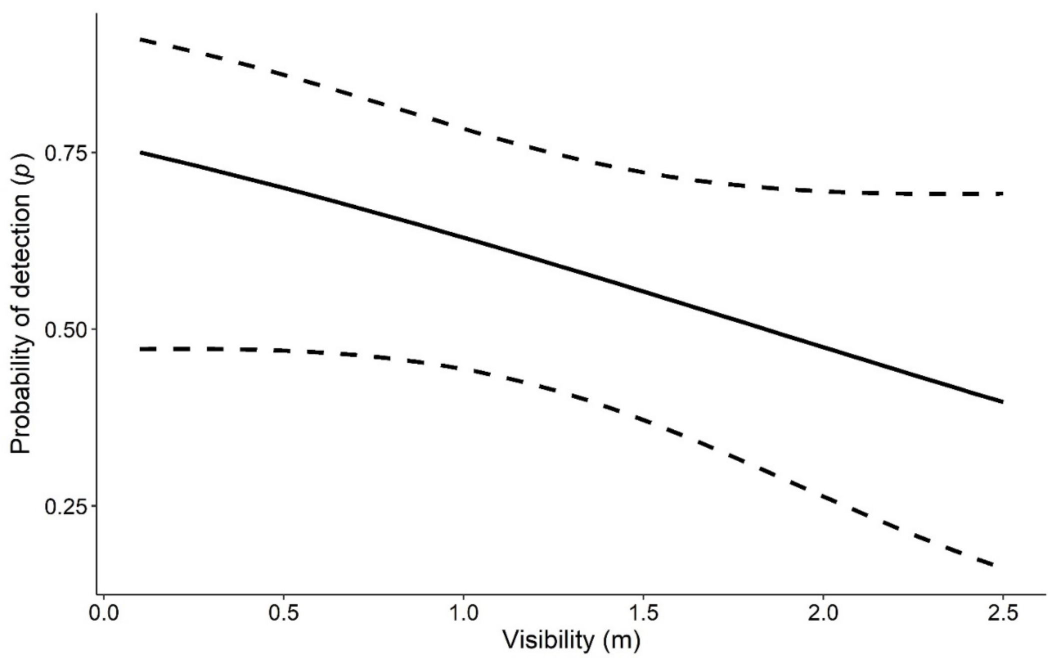

Figure 4. Probability of detecting Rio Grande cooter (*Pseudemys gorzugi*) along the lower Pecos River, estimated from the best-fit model based on survey data from the summer months (May-August) 2020 and 2021. The probability of detecting the species given a site is occupied, was most influenced by water visibility (m), where odds of detection were 1.58 times lower for every 0.73 m increase in water visibility. The 95% confidence intervals are indicated by dashed lines.

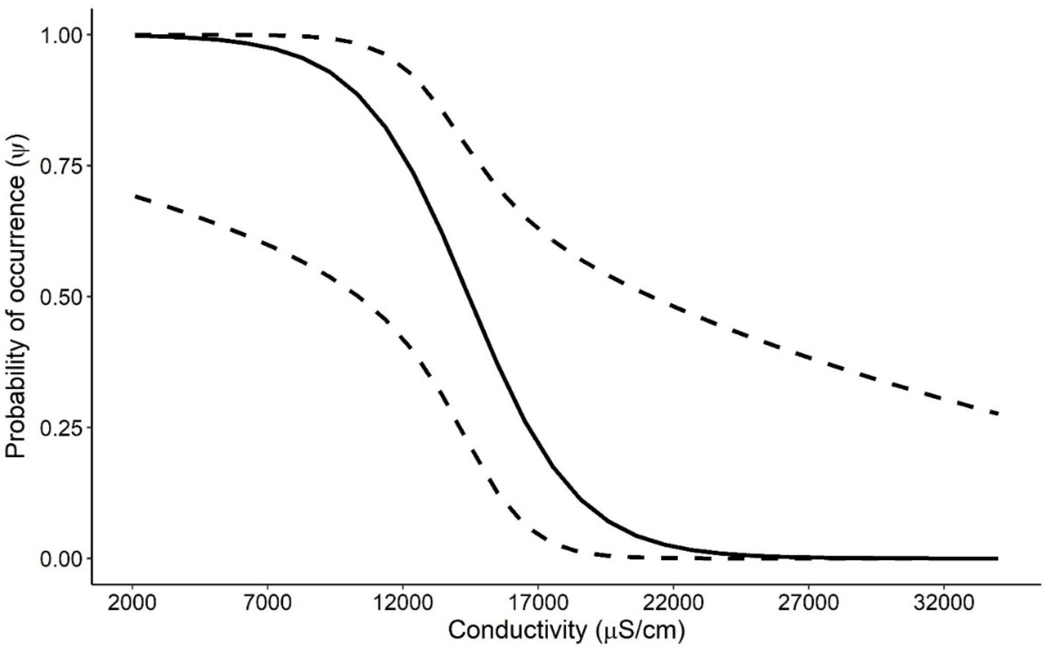

Figure 5. The probability of Rio Grande Cooter (*Pseudemys gorzugi*) occurrence along the lower Pecos River, estimated from the best-fit model based on survey data from the summer months (May-August) 2020 and 2021. The probability of occurrence was significantly influenced by specific conductance (μS/cm), where the odds of the species occupying a site decreased by a factor of 123.46 for every 8719.1 (μS/cm) increase in conductivity. The 95% confidence intervals are indicated by dashed lines.

Table 1. The mean, standard deviation (in parentheses), and range for continuous covariates and frequency for categorical covariates used in a single-season, single-species occupancy model to estimate detection (p) and occupancy (ψ) probabilities for Rio Grande cooter (*Pseudemys gorzugi*) in the lower Pecos River.

Covariate	Parameter	Type	Summary
Flow	ψ	Continuous	Mean (SD): 0.11m/s (0.17 m/s) Range: 0–1.1 m/s
Width	ψ	Continuous	Mean (SD): 51.66 m (53.23 m) Range: 3–346 m
Depth	ψ	Continuous	Mean (SD): 1.38 m (1.15 m) Range: 0.1–6 m
Conductivity	ψ	Continuous	Mean (SD): 10889.02 μS/cm (8719.1 μS/cm) Range: 1424–37397 μS/cm
Dissolved oxygen	ψ	Continuous	Mean (SD): 78.1 mg/L (25.4 mg/L) Range: 21.1–156 mg/L
Landscape condition	ψ	Continuous	Mean (SD): 0.56 (0.24) Range: 0.12–0.95
Basking structures	ψ	Categorical	27 present 5 absent
Aquatic vegetation	ψ	Categorical	14 present 18 absent
Water visibility	ψ, p	Continuous	Mean (SD): 0.56 m (0.5 m) Range: 0–3.5 m
Surface area	p	Continuous	Mean (SD): 29122.78 m^2 (31767.47 m^2) Range: 1598–183727 m^2
Water temperature	p	Continuous	Mean (SD): 27.41 C (3.26 C) Range: 19.65–34.45 C
Day of year	p	Continuous	Mean (SD): 184.49 d (20.28 d) Range: 132–244 d
Atmospheric conditions	p	Categorical	73 sunny days 23 clouded or rainy days
Visual presence of other turtles	p	Categorical	51 present 45 absent

Table 2. Top models from a model selection process using Akaike Information Criterion corrected for small sample size (AICc) to test the probabilities of detection (*p*) and occupancy (ψ) of Rio Grande cooters (*Pseudemys gorzugi*) in the lower Pecos River. Uninformative parameters were excluded. The best-fit model includes water visibility for detection and conductivity for occupancy.

Predictor	K	AICc	Δ AIC	AIC Wt
Detection probability (*p*)				
p(Visibility + Surface Area) ψ(.)	4	99.98	0.00	0.41
p(Surface Area) ψ(.)	3	100.78	0.80	0.28
p(Visibility) ψ(.)	3	101.69	1.71	0.17
p(.) ψ(.)	2	102.19	2.21	0.14
Occupancy probability (ψ)				
p(Visibility) ψ(Conductivity)	4	83.45	0.00	0.51
p(.) ψ(Conductivity)	3	83.50	0.05	0.49

Table 3. The best fit model estimating occupancy and detection probabilities of Rio Grande cooter (*Pseudemys gorzugi*) in the lower Pecos River with parameter estimates, standard errors (SE), and 95% confidence intervals (CI) reported on the logit scale.

		95% CI	
Parameter	**Estimates (SE)**	Lower	Upper
Detection (*p*)			
Intercept	0.341 (0.367)	-0.378	1.059
Visibility	-0.459 (0.305)	-1.056	0.137
Occupancy (ψ)			
Intercept	-1.81 (1.10)	-3.97	0.356
Conductivity	-4.82 (2.15)	-9.037	-0.609

References

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