Section 6 (Texas Traditional) Report Review

Form emailed to FWS S6 coordinator (mm/dd/yyyy): 2/2/2012

TPWD signature date on report: 11/16/2011

Project Title: Abundance and distribution of the threatened minnows *Campostoma ornatum* and *Notropis chihuahua* in the Trans-Pecos region of Texas

Final or Interim Report? Final

Grant #: E-103-R

Reviewer Station: Austin ESFO

Lead station concurs with the following comments: NA (reviewer from lead station)

Interim Report (check one):

- ☐ Acceptable (no comments)
- ☐ Needs revision prior to final report (see comments below)
- ☐ Incomplete (see comments below)

Final Report (check one):

- ☐ Acceptable (no comments)
- ☒ Needs revision (see comments below)
- ☐ Incomplete (see comments below)

Comments:

Referring to these species as "threatened" throughout the report (including the title) could lead to confusion about whether they are federally listed. The report should be revised to clarify this point.

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. TX E-103-R

Endangered and Threatened Species Conservation

Abundance and distribution of the threatened minnows *Campostoma ornatum* and *Notropis chihuahua* in the Trans-Pecos region of Texas

Prepared by:

Dr. Chris Taylor

TEXAS PARKS & WILDLIFE

Carter Smith
Executive Director

Clayton Wolf
Division Director, Wildlife

16 November 2011

FINAL REPORT

STATE: Texas **GRANT NUMBER:** E – 103-R

GRANT TITLE: Abundance and distribution of the threatened minnows *Campostoma ornatum* and *Notropis chihuahua* in the Trans-Pecos region of Texas

REPORTING PERIOD: 1 Oct 08 to 30 Sep 11

OBJECTIVE(S):

To determine seasonal and yearly patterns of abundance, distribution, and habitat use for *Notropis chihuahua* and *Campostoma ornatum* in tributary streams to the Rio Grande in Texas.

Segment Objectives:

Task 1. January 2009. A reconnaissance visit will be made to the region to locate potential sampling sites. Visit with personnel at Big Bend National Park and Big Bend Ranch State Park. Visit with Dr. Bonnie Warnock and Dr. Kevin Urabanczyck at Sul Ross State University; both are conducting water related research in the region.

Task 2. March 2009 (spring sample, year 1). Begin sampling at predetermined localities. Sampling methods are outlined below stated Tasks. After each field trip, samples will be sorted and all data (fish and habitat) will be entered into an Excel database.

Task 3. June 2009 (summer sample, year 1).

Task 4. September 2009 (fall sample, year 1).

Task 5. December 2009 (winter sample, year 1). Completion of first year of study. With four seasonal samples completed, preliminary data analysis and statistical modeling will begin. Preliminary results will be presented at the Texas Chapter of the American Fisheries Society meeting.

Task 6. March 2010 (spring sample, year 2)

Task 7. June 2010 (summer sample, year 2)

Task 8. September 2010 (fall sample, year 2)

Task 9. December 2010 (winter sample, year 2). Completion of second year of study. Final data input, analyses and model selection will be completed. All collected specimens will be delivered to the Ichthyology Collection at the Texas Natural Science Center (TNSC) at The University of Texas at Austin (Dr. Dean Hendrickson, Curator).

Significant Deviation: None.

Summary Of Progress: Please see Attachment A.

Location: Presidio and Brewster Counties, TX

Cost: Costs were not available at time of this report.

Prepared by: Craig Farquhar **Date:** 16 November 2011

Approved by: [signature] **Date:** 16 November 2011

C. Craig Farquhar

ATTACHMENT A

Abundance and distribution of the threatened minnows *Campostoma ornatum* and *Notropis chihuahua* in the Trans-Pecos region of Texas

Principal Investigator:

Dr. Christopher Taylor
Department of Natural Resources Management
Texas Tech University
Lubbock, TX 79413
806-742-1983
cm.taylor@ttu.edu

Graduate Research Assistant:

Seiji Miyazono
Department of Natural Resources Management
Texas Tech University

Final Report

Abstract:

The Rio Grande and its tributaries in the Trans-Pecos region of Texas have been impacted by a variety of anthropogenic activities such as dewatering and the introduction of non-native species. These environmental manipulations have negatively affected the native fishes leading to extirpations and population declines throughout the region. *Campostoma ornatum* and *Notropis chihuahua* inhabit Rio Grande tributary streams in the Trans-Pecos region and are considered as threatened. Little is known about their status and ecological requirements in the region. We hypothesized that the distribution and abundance of these threatened minnows in these spring-fed habitats can be modeled by three primary factors: 1) adequate fish dispersal from the tributaries occurring through the river, 2) local environmental conditions that are maintained by spring flow, and 3) the abundance of introduced species such as the plains killifish, *Fundulus zebrinus*. We used classification and regression trees to analyze variation in abundance/incidence of the target species from Alamito, Terlingua and Tornillo creeks, as well as the Rio Grande proper based on local environmental factors (e.g., stream size and water quality), abundance of nonnative species, season, and distance from the Rio Grande. The analyses indicated that distance from the Rio Grande, maximum depth, and substrate composition were the most important predictors for the abundance and occurrence of the target species in the region.

Introduction

The Rio Grande system in the Trans-Pecos region of Texas contains many unique aquatic species and environments. This aquatic system has been impacted by a variety of anthropogenic activities, including dewatering of the mainstem Rio Grande, and the introduction of nonnative species (Edwards et al. 2002). These environmental manipulations have negatively impacted native fishes, leading to extirpations and population declines throughout the region (Hubbs 1990). In addition, by 2050, the region's population and concomitant municipal water demands are expected to double (Texas Center for Policy Studies 2002), which would further pressure the habitats and aquatic faunas in the Rio Grande system.

Campostoma ornatum (Mexican stoneroller) and *Notropis chihuahua* (Chihuahua shiner) inhabit Rio Grande tributary streams in the Trans-Pecos region and are considered as threatened by the Texas Parks and Wildlife Department, Hubbs et al. (1991), and Miller (1972). Both species are on the Watch List of the Texas Organization for Endangered Species (1988) and listed as special concern by Williams et al. (1989). Little is known about the status and ecological requirement of either species, yet both are native components to desert stream ecosystems that are under considerable stress from declining water quality and quantity (Hubbs and Wauer 1973).

We hypothesized that the distribution and abundance of the target species in spring-fed habitats in the Trans-Pecos region can be modeled by three primary processes: 1) adequate fish dispersal from the tributaries occurring through the river, 2) local environmental factors, and 3) the abundance of nonnative species. Both species sporadically occur in the Rio Grande and may have metapopulation structures, with dispersal from tributaries occurring through the river. We predicted that as the distance between the Rio Grande and its tributary localities increase, the incidence and abundance of these two species would decrease. *Campostoma ornatum* prefers riffles and pools with gravel/rocky substrates and clear, cool water (Contreras-Balderas 1974; Burr 1980a). *Notropis chihuahua* tends to inhabit springs with gravel/sandy bottom and clear, cool water (Burr 1980b; Burr and Mayden 1981). We predicted that pool depth, water clarity, and gravel substrate in the tributaries should be positively related to the incidence and abundance of the target species. Hubbs and Wauer (1973) hypothesized that *Fundulus zebrinus*, a nonnative species, was replacing *C. ornatum* via resource competition in the Tornillo Creek in the Trans-Pecos region. We predicted that the abundance and distribution of the threatened species would be negatively related to the abundance of *F. zebrinus*.

Objectives

The specific objectives of this study were (1) to determine distribution and abundance patterns of the two threatened cyprinid species and (2) determine their environmental associations in the Rio Grande and its tributaries in the Trans-Pecos region of Texas.

Location

The Rio Grande in the Trans-Pecos region is diverted to irrigate fields south and east of El Paso, TX and tends to be slow moving, shallow, channelized, and heavily silted until it receives discharge from the Rio Conchos in Mexico (Fig. 1), its primary tributary (Hubbs et al. 1977; Edwards et al. 2002). The discharge of the Rio Conchos downstream of their junction significantly changes the habitat characteristics of the Rio Grande in comparison to upstream reaches (Bestgen and Platania 1988). The Rio Grande downstream of the Rio Conchos has deeper runs, larger substrate (e.g., cobble and rubble), and lower conductivity and salinity values than the Rio Grande upstream of the Rio Conchos (Bestgen and Platania 1988). The Rio Grande in the Trans-Pecos region also receives water from a series of tributaries including Cibolo, Alamito, Terlingua, and Tornillo creeks. We conducted seasonal fish and environmental monitoring at 3–5 month intervals at Alamito (1 site), Terlingua (3 sites), and Tornillo (1 site) creeks, and the Rio Grande (5 sites) in Presidio and Brewster counties (Fig. 1, sites 1-10; Table 1-8), Texas, U.S.A., from August 2009 to June 2011 (total 79 samples). In addition, regional fish collections were conducted at 27 sites (Fig. 1, sites 11-37; Table 9-10) from October, 2009 through May, 2011.

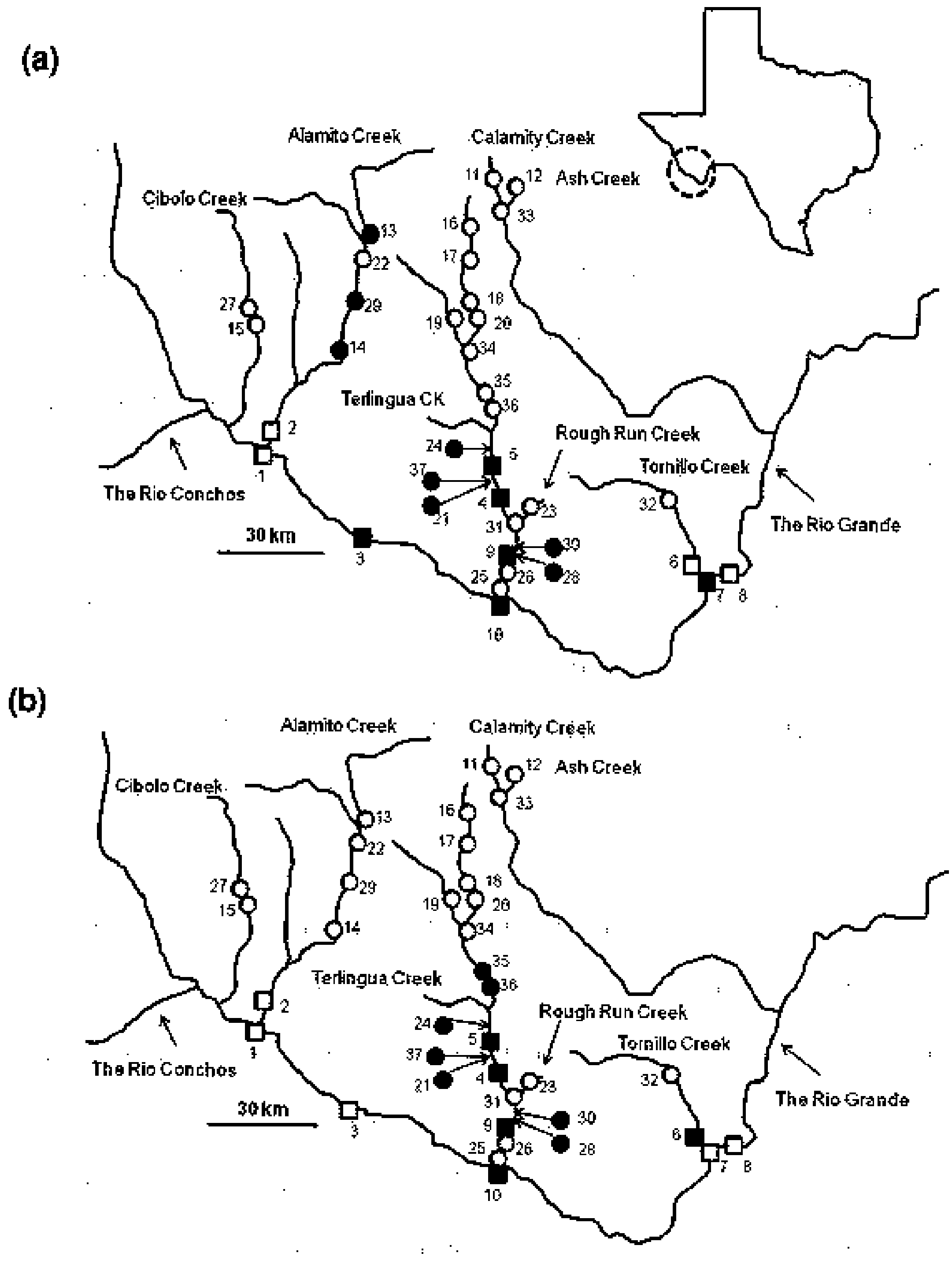

Figure 1. Maps showing 37 sampled sites and distribution of a) *C. ornatum* and b) *N. chihuahua* in 2009–2011. Site numbers correspond to Table 1-37. Squares and circles (solid: presence, empty: absence) indicate monitoring sites and additional regional collection sites, respectively.

Methods

Fish and environmental sampling

Fishes were sampled from each site by seine (4.2 m × 1.7 m, 5 mm mesh), dragged by hand for 30–60 min per site (depending on stream size). We sampled all available habitat types (i.e., riffles, pools, and runs) within a stream reach. Fishes > 25-cm total length were identified, counted, and returned to the water. Smaller fishes were fixed in 10% formalin and returned to the lab for identification and preservation in 50% ethanol. All fish collections will be curated into the Ichthyology Collection at the Texas Natural Science Center.

For each locality where fishes were sampled, an array of habitat data was also collected. Measured environmental variables included temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* concentration. We used a Multiparameter Meter (Hanna Instruments, Schertz, TX, USA) to measure temperature, dissolved oxygen, pH, and specific conductance and used an Aquafluor Handheld Fluorometer and Turbidimeter (Turner Designs, Sunnyvale, CA, USA) to measure turbidity and chlorophyll a concentration. Within each site, we made 5–8 transects perpendicular to stream flow and spaced 10- to 20-m intervals along the sampled stream reach. Mean stream width, depth and substrate composition were then calculated across transects. Substrate was categorized according to Taylor and Lienesch (1996a, b). We measured maximum current velocity of the sampled reach according to Taylor et al. (2008). Water course distance between the Rio Grande and its tributary localities was measured with Google Earth (http://www.google.com/earth/index.html).

Analyses

We used classification and regression trees (CART) to describe the variation in abundance/incidence of the target species based on distance to the Rio Grande, local environmental factors (maximum depth, pH, turbidity, specific conductance, chlorophyll-a concentration, substrate composition, maximum current velocity), the abundance of nonnative fishes (*F. zebrinus* and *Lepomis cyanellus*) and season. The CART methodology recursively splits a matched data set of categorical variables (for classification trees) or continuous variables (for regression trees) into progressively smaller mutually exclusive groups, using binary splits based on single independent or predictor variables (De'ath and Fabricius, 2000; Prasad et al., 2006). CART models have advantages over parametric statistical analyses (e.g., multiple regression models) because of the applicability to cases in which the relationships between variables are strongly nonlinear or involve high-order interactions (Rahel and Jackson 2007). In addition, CART can admit a mix of categorical and continuous variables and is insensitive to monotonic transformations of the predictor variables because they rely on the rank ordering of variables (McCune and Grace 2002; Rahel and Jackson 2007). We used fish incidence data for classification trees (fitting method: Gini index; minimum split index value: 0.05; minimum improvement in the proportion of reduction in error: 0.05; minimum count allowed in each node: 5) and fish abundance data for regression trees (fitting method: least squares; minimum split index value: 0.05; minimum improvement in the proportion of reduction in error: 0.05; minimum count allowed in each node: 5). We conducted the CART analyses for the 79 monitoring samples and the regional data set (five tributary monitoring sites and 27 additional sites throughout the region), separately. SYSTAT 11 (SYSTAT Software, Inc, Richmond, CA, USA) was used to perform the CART analyses.

Results

We caught *C. ornatum* (N = 2590) from 14 of the 37 sampled sites and *N. chihuahua* (N = 1534) from 12 of the 37 sampled sites (Fig. 1, Tables 1 - 10). *Campostoma ornatum* occurred in Alamito Creek (mean abundance = 115.7), Terlingua Creek (mean abundance = 30.6), and the Rio Grande (mean abundance = 0.1). *Notropis chihuahua* occurred in Terlingua Creek (mean abundance = 38.6), Tornillo Creek (mean abundance = 0.1), and the Rio Grande (mean abundance = 0.6).

A classification tree using distance from the Rio Grande and season explained 62% of the variation in incidence of *C. ornatum* at the 10 monitoring sites. The first split in the classification tree of incidence for *C. ornatum* was based on distance from the Rio Grande at a value of 3.7 km (Fig. 2a). In other words, the mean incidence of *C. ornatum* at monitoring sites on and near the Rio Grande (< 3.7 km, Alamito and Tornillo creek sites) was considerably lower (mean incidence = 0.05) than at monitoring sites further from the Rio Grande (sites 4, 5, and 9 in Terlingua Creek; mean incidence = 0.62), which were well upstream of the confluence with the river. The second split in the classification tree of *C. ornatum* incidence (Fig. 2a) at the monitoring sites was also based on distance from the Rio Grande at a value of 20.8 km. Thus, occurrences of *C. ornatum* were more prevalent at the most upstream Terlingua Creek monitoring site (mean incidence = 1). The third split in the classification tree for *C. ornatum* occurrence (Fig. 2a) was based on season. The mean incidence of *C. ornatum* at Terlingua Creek monitoring sites from August to November was lower (mean incidence = 0.12) than from March to June (mean incidence = 0.75). A regression tree (based on abundance rather than incidence) using distance from the Rio Grande (split occurred at 20.8 km) explained 38% of the variation in abundance of *C. ornatum* in the 10 monitoring sites (Fig. 2b). The split divided the upstream Terlingua Creek monitoring site from all others. *Campostoma ornatum* had a mean abundance of 98.6 individuals at this site, which was considerably higher than the other monitoring sites where the species occurred (mean abundance = 3.7). To summarize, *C. ornatum* occupied Terlingua Creek throughout the study, but was more prevalent at the most upstream monitoring site and during the spring season. *Campostoma ornatum* occurred minimally in the Rio Grande sites.

For *N. chihuahua*, a classification tree using distance from the Rio Grande (3.7 km; Fig. 3a) explained 78% of the variation in incidence of *N. chihuahua* across the 10 monitoring sites. Thus, as with *C. ornatum*, the incidence of *N. chihuahua* was highest at the Terlingua Creek monitoring sites (mean incidence = 0.95) and was considerably lower elsewhere (mean incidence = 0.05). A regression tree using maximum depth (split at 1.8 m) explained 15% of the variation in abundance of *N. chihuahua* across the 10 monitoring sites. In other words, the mean abundance of *N. chihuahua* was highest where deep pool habitat was found (mean abundance = 107.1 vs 8.0). To summarize, *N. chihuahua* occupied Terlingua Creek monitoring sites throughout the study, but was most abundant in the deeper, spring-fed pools of Terlingua Creek.

The regional analyses for *C. ornatum* were more complex than the monitoring site analyses. For *C. ornatum* incidence the first split was again based on distance from the Rio Grande. However, this split largely separated the Terlingua Creek occurrences (right split, all in the lower one-half of the drainage) from those in Alamito Creek (left split, all in the upper one-half of the drainage). This odd distribution pattern seems confusing until the habitat is considered. Gravel substrates were prevalent in upper Alamito Creek and corresponded to a relatively high level of *C. ornatum* occurrence (mean occurrence = 0.4). The Terlingua Creek branch was further split by distance such that lower 3.9 km of stream above the confluence with the Rio Grande contained a relatively low level of incidence (mean incidence = 0.2) compared to the localities between 3.9 and 28 km upstream of the confluence (mean incidence = 0.8). The final split separated the high occurrence localities in Terlingua Creek based on the amount of mud substrate present; high levels of mud substrate corresponded to lower levels of occurrence. Much of the upper Terlingua Creek watershed had muddy or bedrock substrates that were lacking in high percentages of gravel, and in *C. ornatum* occurrence. A regression tree based on abundance and using distance from the Rio Grande and gravel substrate composition explained 25% of the variation in abundance of *C. ornatum* across the 32 regional sites. The first split in the regression tree of abundance of *C. ornatum* was based on gravel substrate composition at a value of 38.8% (Fig. 4b). In other words, the mean abundance of *C. ornatum* at regional sites with less gravel (percentage of gravel substrate < 38.8; mean abundance = 8.9) was considerably lower than for sites with higher gravel composition (percentage of gravel substrate ≥ 38.8; mean abundance = 114.8). The second split in this regression tree was based on distance from the Rio Grande at a value of 23.4 km. Thus, *C. ornatum* was more abundant at upstream Alamito Creek sites with high gravel substrate composition (≥ 23.4 km; mean abundance = 231.5). To summarize, *C. ornatum* was more prevalent in lower reaches of Terlingua Creek where muddy substrates were lacking, but was more abundant in upper reaches of Alamito Creek where higher gravel substrate composition was found.

For *N. chihuahua*, a classification tree using distance from the Rio Grande (split at 23.4 km) explained 36% of the variation in incidence across the 32 regional sites (Fig. 5a). *Notropis chihuahua* incidence was limited to only one tributary sample (Tornillo Creek) outside of Terlingua Creek, and all Terlingua creek occurrences were in the lower one-half of the drainage. The second split in the classification tree was also based on distance from the Rio Grande at values of 3.9 km and indicated that the localities near the Rio Grande confluence held fewer occurrences than localities further upstream (>3.9 km). A regression tree using distance from the Rio Grande and maximum depth explained 21% of the variation in abundance of *N. chihuahua* across the 32 regional sites. The first split was based on distance from the Rio Grande (21.3 km) and the second was based on maximum depth (0.76 m) (Fig. 5b). Thus, localities in the lower reaches of Terlingua Creek that had deep pool habitats contained the most *N. chihuahua* individuals.

Discussion

Our results indicated that *C. ornatum* and *N. chihuahua* primarily inhabited tributary systems to the Rio Grande, but responded differentially to measured environmental factors. The result of the CART analyses indicated that *C. ornatum* permanently occurred through much of the lower Terlingua Creek system and were more prevalent in the spring season (March-June). Hubbs and Wauer (1973) reported that young and breeding adult were present in January, and half-grown young in May and June in Tornillo Creek, suggesting that the breeding season of *C. ornatum* was winter to spring. Because most *C.*

ornatum we collected in the downstream localities of Terlingua Creek were young of year, *C. ornatum* appeared to have spawned in Terlingua Creek in winter to spring and may have used the downstream localities for nursery sites. Conversely, season was not a predictor for the incidence of *N. chihuahua* and we collected *N. chihuahua* throughout most of Terlingua Creek. Maximum pool depth was positively related to the abundance of *N. chihuahua*, suggesting that *N. chihuahua* may persist in the deep tributary habitats in Terlingua Creek.

Substrate composition was an important predictor for the incidence and abundance of *C. ornatum* in the regional analysis. Both incidence and abundance of *C. ornatum* were positively related to the percentage of gravel substrate. *Campostoma ornatum* is an herbivorous, bottom feeder (Contreras-Balderas 1974) and constructs spawning pits (Johnston 1999). *Notropis chihuahua* is invertivore (Burr and Mayden 1981) and is likely a broadcast spawner (Johnston 1999). *C. ornatum* may rely on substrate for their foraging and spawning more than *N. chihuahua* in our system.

Historical fish assemblage records (1977-1989) showed that both *C. ornatum* and *N. chihuahua* occurred at our downstream locality (monitoring site) in Alamito Creek (Hubbs et al. 1977; Bestgen and Platania 1988; Linam et al. 2002). However, we did not collect either species at that locality. Our analysis indicated that pool depth and the percentage of gravel substrate were important variables in our study system. These habitats were lacking at the monitoring site in Alamito Creek. Furthermore, this site has been strongly impacted by cattle (personal observation), possibly affecting the ability of either species to persist at this locality.

Hubbs and Wauer (1973) hypothesized that *F. zebrinus* might be replacing *C. ornatum* in the Tornillo Creek. In 1954, *C. ornatum* was the dominant species in the Tornillo Creek (Hubbs and Wauer 1973), occurring in five of 11 samples in from 1967-1970. We did not collect any *C. ornatum* from Tornillo Creek. Conversely, *F. zebrinus* has expanded their distribution and abundance in our study system since 1956 (Hubbs and Wauer 1973). Hubbs and Wauer (1973) reported that *F. zebrinus* occurred in nine of 11 samples and was abundant in the creek in the spring months from 1967-1970. We found *F. zebrinus* in all of our Tornillo Creek samples; thus, they appear to be persisting indefinitely in the creek. Although the abundance of *F. zebrinus* was not negatively related to the abundance and incidence of either of the threatened species in our CART analyses, *F. zebrinus* is now widespread and abundant in the region and may have impacts to native species that are yet to be seen. In addition, red shiners (*Cyprinella lutrensis*), are now a dominant species in lower Alamito and Tornillo creeks, and their impact on the target species in this system is unknown and should be further studied.

The effects of environmental change in the Rio Grande tributary systems needs to be incorporated in decisions concerning restoration efforts. Our results indicated that *C. ornatum* and *N. chihuahua* tend to primarily inhabit tributary systems to the Rio Grande in the Trans-Pecos region. However, both species historically occurred at our Alamito Creek (heavily impacted by cattle) and Tornillo Creek monitoring sites, where they now no longer persist. Management goals associated with maintaining populations of these species in the tributaries may be attainable through developing management frameworks that restore and maintain habitat connectivity and conditions, and optimal flow regimes that favor native faunas and minimize the impact of biological invasion.

Table 1. Sample information, measured environmental variables, and fish species collected in long-term monitoring sites in August 2009. Sample numbers correspond to Figure 1.

	1	2	3	4	5	6	7	8	9	10
Sample Information										
Date	8/18/09	8/18/09	8/19/09	8/19/09	8/19/09	8/20/09	8/20/09	8/20/09	8/21/09	8/21/09
GPS (North)	29.5207	29.5213	29.3363	29.3119	29.3274	29.1775	29.1777	29.1797	29.1968	29.1644
GPS (West)	104.2927	104.2919	104.0556	103.5472	103.5537	103.0009	102.9974	102.9609	103.6059	103.6096
Environmental Variables										
Elevation (ft)	2542	2548	2415	2481	2512	1842	1833	1801	2201	2160
Water temp (C°)	29.00	30.54	.	.	.	.	.	.	.	.
pH	7.68	7.56	8.00	8.18	7.91	8.33	8.18	8.06	8.07	8.10
Dissolved oxygen (mg/L)	9.65	5.66	.	.	.	.	.	.	.	.
Conductivity (µS/cm)	2568.00	556.00	1420.00	1560.00	1640.00	1145.00	1819.00	1790.00	1285.00	1952.00
Mean turbidity (NTU)	59.83	9.24	21.41	8.41	12.37	6.26	23.45	21.01	7.31	50.15
Mean chlorophyll-a (µg/L)	28.67	1.41	4.25	1.33	1.30	1.99	3.23	2.92	1.09	4.26
Species										
Dorosoma cepedianum	6	0	0	0	0	0	0	0	0	1
Campostoma ornatum	0	0	0	0	62	0	1	0	0	0
Cyprinella lutrensis	587	22	224	307	123	369	207	186	182	414
Cyprinus carpio	4	0	0	0	0	0	0	0	5	0
Hybognathus amarus	0	0	0	0	0	0	0	0	5	0
Macrhybopsis aestivalis	14	0	6	0	0	0	1	3	0	31
Notropis braytoni	5	0	25	77	45	0	16	9	148	211
Notropis chihuahua	0	0	0	11	5	0	0	0	47	0
Pimephales promelas	0	0	1	0	0	0	0	0	0	0
Rhinichthys cataractae	4	0	1	0	0	0	0	0	0	3
Carpiodes carpio	22	22	14	14	8	291	31	44	34	70
Cycleptus elongatus	0	0	1	0	0	0	0	1	0	0
Astyanax mexicanus	16	0	15	9	5	89	3	8	36	12
Ictalurus furcatus	0	0	3	5	0	0	3	28	2	3
Ictalurus punctatus	15	0	57	4	0	0	16	19	41	54
Pylodictis olivaris	1	0	0	0	0	0	0	2	0	0
Menidia beryllina	0	0	2	0	0	0	0	0	0	1
Gambusia affinis	24	126	11	0	0	1	1	1	0	1
Fundulus zebrinus	0	0	0	52	42	154	0	0	60	0
Lepomis macrochirus	2	0	0	0	0	0	0	0	0	0
Lepomis megalotis	4	0	0	0	0	0	0	0	0	8
Micropterus salmoides	1	0	0	0	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	0	0	0	0	1

Table 2. Sampling date, measured environmental variables, and fish species collected in long-term monitoring sites in November 2009. Sample numbers correspond to Figure 1.

	1	2	3	4	5	6	7	8	9	10
Date	11/17/09	11/16/09	11/17/09	11/18/09	11/17/09	11/19/09	11/18/09	11/19/09	11/18/09	11/19/09
Environmental variables										
Water temp (C°)	14.02	21.4	16.83	17.35	19.84	25.08	19.64	18.8	15.6	14.67
pH	8.12	7.77	8.07	8.07	8	8.06	7.83	7.96	8.17	8.07
Dissolved oxygen (mg/L)	8.45	5.4	9.13	7	9.32	7.41	8.06	7.75	8.78	8.28
Conductivity (µS/cm)	2898	607	2787	1615	1654	1055	2328	2325	1238	2567
Mean turbidity (NTU)	46.52	4.98	24.27	4.40	5.89	5.29	19.10	15.90	6.41	20.06
Total dissolved solids (mg/L)	1449	304	1394	808	825	527	1164	1163	619	1283
Chlorophyll-a (µg/L)	19.89	1.76	11.71	1.11	1.60	1.54	3.28	3.15	1.83	6.24
Boulder (%)	11.1	0	9.1	0	0	0	36.6	3.3	0	3.57
Cobble (%)	48.1	0	36.3	5.5	5.5	5.5	26.6	23.3	23.5	25
Gravel (%)	33.3	27.7	27.2	66.6	66.6	72.2	30	60	29.4	57.14
Sand (%)	0	72.2	0	16.6	16.6	22.2	6.6	10	5.8	7.14
Mud (%)	7.4	0	27.2	11.1	11.1	0	0	3.3	41.1	7.14
Pool length (m)	150	100	160	75	65	500	160	250	160	200
Mean site width (m)	45.33	2.48	71.75	5.24	14.00	7.14	40.10	58.00	19.90	26.80
Maximum depth (m)	1.7	0.3	2	0.63	0.75	0.5	1.2	1.2	2	1.3
Mean depth (m)	0.93	0.046	1.34	0.38	0.16	0.138	0.8	0.845	0.78	0.76
Max. current velocity (s/m)	0.67	0.19	1.49	0.33	0.25	0.33	0.70	0.43	1.00	1.52
Species										
Dorosoma cepedianum	0	0	2	0	0	0	0	0	0	0
Campostoma ornatum	0	0	0	0	13	0	0	0	27	0
Cyprinella lutrensis	520	38	287	282	382	1224	327	602	371	1046
Cyprinus carpio	0	0	0	0	0	0	0	0	0	0
Hybognathus amarus	0	0	0	1	0	0	0	14	0	20
Macrhybopsis aestivalis	14	0	2	0	0	1	1	5	14	18
Notropis braytoni	20	0	24	56	97	404	133	126	55	422
Notropis chihuahua	0	0	0	22	12	0	0	0	54	0
Pimephales promelas	6	0	1	1	0	0	0	0	0	0
Rhinichthys cataractae	2	0	14	0	0	0	0	0	0	7
Carpiodes carpio	5	0	42	34	1	17	3	41	0	62
Cycleptus elongatus	0	0	0	0	0	0	0	1	0	2
Moxostoma congestum	1	0	0	0	0	0	0	0	0	0
Astyanax mexicanus	10	0	24	6	17	39	0	1	0	3
Ictalurus furcatus	0	0	1	0	0	0	0	5	0	0
Ictalurus punctatus	1	0	37	1	0	0	5	17	2	35
Pylodictis olivaris	0	0	0	0	0	0	1	0	0	0
Menidia beryllina	0	0	11	0	0	0	0	0	0	0
Gambusia affinis	5	221	16	0	0	180	7	6	0	8
Fundulus zebrinus	0	0	0	73	193	32	0	0	2	3
Lepomis cyanellus	0	0	0	1	0	0	0	0	0	0
Lepomis megalotis	3	0	1	0	0	0	0	0	0	0

Table 3. Sample date, measured environmental variables, and fish species collected in long-term monitoring sites in March 2010. Sample numbers correspond to Figure 1.

	1	2	3	4	5	6	7	8	9	10
Date	3/16/10	3/15/10	3/16/10	3/16/10	3/16/10	3/17/10	3/17/10	3/17/10	3/18/10	3/18/10
Environmental variable										
Water temp (C°)	15.5	21.53	17.68	20.3	20.57	28.19	18.69	17.63	13.71	15.16
pH	8.14	7.76	8.02	8.12	7.93	7.69	7.79	7.93	7.79	7.8
Dissolved oxygen (mg/L)	12.27	8.1	11.51	10.82	11.97	12.03	11.3	10.83	12.74	11.6
Conductivity (µS/cm)	3487	663	3286	1753	1703	620	2437	2358	1219	3180
Turbidity (NTU)	20.72	3.21	23.70	11.36	4.20	3.02	11.40	15.23	10.17	23.15
Total dissolved solids (mg/L)	1743	330	1643	877	852	315	1219	1180	609	1587
Chlorophyll-a (µg/L)	40.07	0.86	12.02	0.49	0.49	1.30	6.10	7.33	1.49	9.04
Boulder (%)	11	0	4	0	0	0	27	3	0	0
Cobble (%)	59	0	26	22	12	0	40	20	22	18
Gravel (%)	19	78	37	67	71	100	30	53	17	68
Sand (%)	0	22	4	11	12	0	3	23	0	7
Mud (%)	11	0	30	0	6	0	0	0	61	7
Pool length (m)	150	100	150	100	80	250	150	225	150	200
Mean site width (m)	71.17	2.32	66.00	4.69	8.98	6.20	40.80	59.80	20.00	30.60
Max depth (m)	2	0.36	1.5	0.52	0.66	0.1	1.1	1.2	2	1.1
Mean pool depth (m)	0.76	0.07	0.95	0.24	0.12	0.078	0.82	0.85	0.54	0.65
Max. current velocity (m/s)	1	0.66	4	0.3	0.13	0.33	2.5	1	1	2
Species										
Lepisosteus osseus	0	0	0	0	0	0	0	0	0	1
Dorosoma cepedianum	0	0	0	0	0	0	0	0	0	1
Campostoma ornatum	0	0	1	12	35	0	0	0	58	4
Cyprinella lutrensis	1786	0	1002	325	528	1257	573	649	1056	969
Cyprinus carpio	2	0	0	0	0	0	0	0	0	0
Hybognathus amarus	0	0	5	0	0	0	1	2	1	3
Macrhybopsis aestivalis	12	0	7	0	0	0	13	31	1	36
Notropis braytoni	51	0	175	72	279	36	172	110	48	195
Notropis chihuahua	0	0	0	7	35	0	0	0	624	0
Rhinichthys cataractae	0	0	4	0	0	1	5	5	0	9
Carpiodes carpio	1	0	22	15	9	0	0	1	0	49
Cycleptus elongatus	0	0	1	0	0	0	7	3	0	1
Moxostoma congestum	2	0	0	0	0	0	0	0	0	0
Astyanax mexicanus	0	0	2	0	2	3	1	0	0	0
Ictalurus furcatus	0	0	0	0	0	0	0	0	0	0
Ictalurus punctatus	2	0	7	0	0	0	1	0	0	6
Pylodictis olivaris	0	0	1	0	0	0	0	0	0	0
Gambusia affinis	0	0	6	0	0	61	31	0	0	0
Fundulus zebrinus	0	0	0	15	101	60	0	1	58	0

Table 4. Sampling date, measured environmental variables, and fish species collected in long-term monitoring sites in June 2010. Sample numbers correspond to Figure 1.

	1	2	3	4	5	6	7	8	9	10
Date	6/2/10	6/2/10	6/3/10	6/3/10	6/3/10	6/4/10	6/4/10	6/4/10	6/4/10	6/4/10
Environmental variable										
Water temp (C°)	29.12	24.87	24.16	25.22	30.04	30.34	29.28	28.97	24.85	29.03
pH	8.02	7.45	7.91	7.53	7.6	7.71	7.7	7.76	7.79	7.94
Dissolved oxygen (mg/L)	8.65	2.9	5.43	4.5	4.96	7.36	6.78	6.52	8.25	8.61
Conductivity (µS/cm)	2374	498	2201	1596	1101	1098	2559	2471	1240	3396
Turbidity (NTU)	43.02	5.50	79.07	6.64	6.50	2.58	85.47	50.38	12.01	60.51
Total dissolved solids (mg/L)	1186	310	1100	798	551	549	1281	1236	620	1698
Chlorophyll-a (µg/L)	17.60	0.88	19.87	0.52	0.48	1.01	8.34	7.24	0.29	14.97
Boulder (%)	0	0	24	0	0	0	8	3	0	10
Cobble (%)	26	0	28	44	11	6	15	23	6	23
Gravel (%)	37	17	31	44	83	39	46	47	22	67
Sand (%)	15	83	0	6	6	56	12	0	17	0
Mud (%)	22	0	17	6	0	0	19	27	50	0
Bedrock (%)	0	0	0	0	0	0	0	0	6	0
Pool length (m)	150	100	150	75	80	250	200	225	150	200
Site wetted-width (m)	19.4	3.8	33.9	4.2	8.9	2.5	43.0	46.0	10.2	26.0
Max depth (m)	1.5	0.17	1.3	0.49	0.7	0.15	1.2	1.2	1.8	0.81
Avg pool depth (m)	0.70	0.10	0.65	0.23	0.31	0.08	0.64	0.83	0.76	0.58
Max. curr. velocity (m/s)	3.00	0.75	1.50	0.03	0.75	0.42	1.50	1.13	0.43	0.82
Species										
Lepisosteus osseus	0	0	1	0	0	.	1	20	0	0
Dorosoma cepedianum	6	0	139	0	0	.	0	0	0	1
Campostoma ornatum	0	0	0	4	116	.	0	0	45	0
Cyprinella lutrensis	882	4	1052	114	108	.	101	501	183	1224
Cyprinus carpio	67	0	23	0	0	.	1	0	0	1
Hybognathus amarus	0	0	0	0	0	.	0	11	1	36
Macrhybopsis aestivalis	45	0	3	0	0	.	23	48	0	21
Notropis braytoni	59	0	168	12	94	.	187	211	40	101
Notropis chihuahua	0	0	0	1	5	.	0	0	114	25
Notropis jemezanus	0	0	0	0	0	.	0	0	0	2
Rhinichthys cataractae	6	0	15	0	0	.	1	0	0	108
Carpiodes carpio	26	2	128	1	9	.	26	64	3	118
Cycleptus elongatus	0	0	0	0	0	.	0	4	0	4
Moxostoma congestum	0	0	2	0	0	.	0	0	0	0
Astyanax mexicanus	0	0	0	2	11	.	5	0	25	0
Ictalurus furcatus	0	0	4	0	0	.	0	1	0	0
Ictalurus punctatus	3	0	56	0	0	.	4	0	4	55
Pylodictis olivaris	0	0	1	0	0	.	0	2	0	0
Menidia beryllina	20	0	0	0	0	.	0	0	0	0
Gambusia affinis	35	1	110	0	0	.	8	115	0	0
Fundulus zebrinus	0	0	0	12	38	.	25	0	182	27
Lepomis cyanellus	1	0	0	1	0	.	0	0	0	1
Lepomis megalotis	5	0	0	0	0	.	3	3	0	0

Table 5. Sampling date, measured environmental variables, and fish species collected in long-term monitoring sites in August 2010. Sample numbers correspond to Figure 1.

	1	2	3	4	5	6	7	8	9	10
Date	8/16/10	8/16/10	8/17/10	8/17/10	8/17/10	8/18/10	8/18/10	8/18/10	8/17/10	8/18/10
Environmental variable										
Water temp (C°)	29.29	29.97	28.22	31.71	27.64	33.66	28.77	27.74	33.69	31.77
pH	8.07	7.68	8.09	8.11	8.02	8.08	7.8	7.77	7.89	8.13
Dissolved oxygen (mg/L)	5.01	2.75	5.77	6.25	6.28	6.42	5.57	5.62	5.79	6.71
Conductivity (µS/cm)	1071	463	1094	412	240	860	465	519	494	983
Mean turbidity (NTU)	211.73	9.57	159.33	4.46	49.23	28.94	65.85	203.43	41.08	209.00
Total dissolved solids (mg/L)	535	231	547	206	120	430	232	260	247	489
Salinity	0.52	0.22	0.54	0.19	0.11	0.41	0.22	0.25	0.23	0.48
Mean chlorophyll-a (µg/L)	11.42	1.07	13.25	13.67	15.55	1.63	10.06	10.85	11.51	9.88
Boulder (%)	11.11	0.00	0.00	5.56	0.00	0.00	11.11	5.00	5.88	5.56
Cobble (%)	44.44	0.00	0.00	11.11	11.11	0.00	44.44	20.00	5.88	38.89
Gravel (%)	33.33	44.44	44.44	72.22	61.11	66.67	27.78	30.00	17.65	38.89
Sand (%)	11.11	55.56	0.00	11.11	11.11	33.33	5.56	5.00	41.18	11.11
Mud (%)	0.00	0.00	56.00	0.00	11.11	0.00	11.11	40.00	5.88	5.56
Bedrock (%)	0.00	0.00	0.00	0.00	5.56	0.00	0.00	0.00	23.53	0.00
Pool length (m)	150	100	150	100	80	250	200	225	150	200
Mean site width	31.67	2.33	33.83	6.90	4.40	2.26	54.80	65.00	7.30	82.00
Max depth (m)	1.1	0.15	1.5	0.67	0.66	0.31	1	1.5	2	1
Avg pool depth (m)	0.35	0.08	0.51	0.24	0.22	0.13	0.41	0.50	0.57	0.27
Max. curr. velocity (m/s)	1	1	1.66	0.81	0.64	0.75	0.85	0.47	1	1.1
Lepisosteus osseus	0	0	1	0	0	0	0	0	0	0
Dorosoma cepedianum	1	0	1	0	0	0	1	0	0	6
Campostoma ornatum	0	0	0	0	1	0	0	0	0	0
Cyprinella lutrensis	1152	256	322	126	71	695	113	2	182	159
Cyprinus carpio	3	1	1	0	0	1	5	1	0	3
Hybognathus amarus	0	0	1	0	0	1	0	0	0	0
Macrhybopsis aestivalis	22	0	48	0	0	1	2	2	1	62
Notropis braytoni	82	0	132	38	66	192	102	3	188	318
Notropis chihuahua	0	0	0	10	4	1	0	0	18	0
Carpiodes carpio	12	0	0	4	0	127	6	0	8	10
Astyanax mexicanus	0	0	0	3	8	50	0	0	18	0
Ictalurus furcatus	2	0	52	0	0	0	2	4	10	1
Ictalurus punctatus	16	0	48	2	4	4	3	4	8	32
Pylodictis olivaris	1	0	0	1	1	0	1	0	1	1
Menidia beryllina	0	0	0	0	0	0	0	0	0	0
Gambusia affinis	0	7	7	0	0	1	0	1	0	1
Fundulus zebrinus	0	0	0	23	46	3	0	0	8	0
Lepomis cyanellus	0	1	0	0	1	0	0	0	0	0

Table 6. Sampling date, measured environmental variables, and fish species collected in long-term monitoring sites in November 2010. Sample numbers correspond to Figure 1.

Site	1	2	3	4	5	6	7	8	9	10
Date	11/12/10	11/12/10	11/13/10	11/19/10	11/19/10	11/20/10	11/20/10	11/20/10	11/13/10	11/13/10
Environmental variable										
Water temp (C°)	17.27	22.17	15.63	17.49	20.01	25.06	17.67	20.43	18.53	15.09
pH	8.21	7.79	8.05	8.06	7.48	8.22	7.83	8.02	8.07	8.2
Dissolved oxygen (mg/L)	12.68	5.11	6.67	4.25	3.53	8.56	5	6.8	6.87	7.74
Conductivity (µS/cm)	2158	427	2294	1560	1951	901	2232	2225	953	2332
Mean turbidity (NTU)	46.61	4.99	16.43	14.38	8.43	7.27	18.11	21.55	14.65	24.76
Total dissolved solids (mg/L)	1078	213	1147	845	975	450	1116	1113	575	1166
Salinity	1.11	0.2	1.19	0.85	1	0.44	1.15	1.14	0.47	1.21
Mean chlorophyll-a (µg/L)	32.28	0.78	15.47	2.98	2.09	2.65	2.91	3.05	2.48	8.58
Boulder (%)	16.67	0.00	5.56	5.56	0.00	0.00	11.11	5.56	0.00	5.56
Cobble (%)	61.11	0.00	11.11	38.89	11.11	0.00	33.33	16.67	0.00	50.00
Gravel (%)	16.67	16.67	33.33	50.00	77.78	72.22	16.67	72.22	22.22	33.33
Sand (%)	0.00	83.33	5.56	6.00	11.11	11.11	11.11	5.56	11.11	5.56
Mud (%)	5.56	0.00	44.44	0.00	0.00	16.67	27.78	0.00	55.56	5.56
Bedrock (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.11	0.00
Pool length (m)	150	80	150	104	84	150	150	150	100	150
Mean site width	57.00	4.65	22.42	5.67	4.72	2.46	20.30	23.42	8.30	32.40
Max depth (m)	0.81	0.38	1.2	0.9	0.5	0.235	0.8	1.2	1.5	0.57
Avg pool depth (m)	0.43	0.19	0.80	0.39	0.36	0.14	0.52	0.53	1.07	0.44
Max. curr. velocity (m/s)	0.75	1	1.29	0.25	0.5	0.86	0.9	1	0.6	1.5
Lepisosteus osseus	0	0	0	0	0	0	1	0	0	0
Dorosoma cepedianum	0	0	0	0	0	0	0	0	1	2
Campostoma ornatum	0	0	0	0	21	0	0	0	0	0
Cyprinella lutrensis	1419	163	157	258	314	679	432	198	150	309
Cyprinus carpio	9	0	0	0	0	4	0	0	0	0
Hybognathus amarus	0	0	1	0	0	0	8	66	22	8
Macrhybopsis aestivalis	2	0	0	0	0	0	0	0	6	1
Notropis braytoni	153	0	6	56	206	35	133	83	186	145
Notropis chihuahua	0	0	0	0	9	0	0	0	4	0
Pimephales promelas	0	0	0	1	0	1	0	0	0	0
Rhinichthys cataractae	1	0	4	0	0	0	0	0	0	2
Carpiodes carpio	15	0	0	89	49	1	11	79	67	8
Cycleptus elongatus	0	0	0	0	0	0	0	0	0	1
Astyanax mexicanus	5	0	0	5	21	45	2	0	0	0
Ictalurus furcatus	0	0	0	0	0	0	0	2	1	0
Ictalurus punctatus	7	0	0	11	0	0	0	0	32	1
Pylodictis olivaris	1	0	0	0	0	0	1	0	0	0
Menidia beryllina	0	0	0	0	0	0	0	0	0	13
Gambusia affinis	8	156	0	0	0	61	22	15	8	0
Fundulus zebrinus	0	0	0	0	148	98	0	1	6	1
Lepomis cyanellus	1	0	0	0	0	0	0	0	0	0
Oreochromis aurea	1	0	0	0	0	0	0	0	0	0

Table 7. Sampling date, measured environmental variables, and fish species collected in long-term monitoring sites in March 2011. Sample numbers correspond to Figure 1.

Site	1	2	3	4	5	6	7	8	9	10
Date	3/14/11	3/15/11	3/14/11	3/14/11	3/14/11	3/13/11	3/13/11	3/12/11	3/13/11	3/13/11
Environmental variable										
Water temp (C°)	22.79	18.83	19.43	14.94	19.22	21.23	23.52	26.97	24.93	19.77
pH	8.2	7.74	8.16	7.67	7.4	8.14	7.62	7.83	8.1	8.3
Dissolved oxygen (mg/L)	15.58	5.11	9.62	1.57	3.54	9.45	3.75	6.27	8.93	8.67
Conductivity (µS/cm)	3408	455	3045	1306	1813	856	2043	1309	990	2901
Mean turbidity (NTU)	37.24	12.13	70.86	17.68	13.65	7.87	16.25	16.00	19.37	39.34
Total dissolved solids (mg/L)	1703	228	1521	653	907	428	1022	654	495	1451
Salinity	1.79	0.22	1.59	0.66	0.93	0.42	1.04	0.65	0.49	1.51
Mean chlorophyll-a (µg/L)	25.79	5.28	45.91	6.45	3.61	4.23	18.69	5.94	4.44	33.40
Boulder (%)	11.11	0.00	5.56	5.56	0.00	0.00	11.11	5.56	5.56	4.76
Cobble (%)	27.78	0.00	22.22	11.11	11.11	0.00	33.33	22.22	11.11	28.57
Gravel (%)	22.22	11.11	33.33	72.22	61.11	27.78	27.78	50.00	27.78	28.57
Sand (%)	11.11	88.89	16.67	11.11	27.78	44.44	11.11	11.11	16.67	9.52
Mud (%)	27.78	0.00	22.22	0.00	0.00	27.78	16.67	11.11	38.89	28.57
Bedrock (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pool length (m)	200	80	150	100	75	150	150	150	100	150
Mean site width	43.00	8.73	32.83	3.99	5.18	4.55	25.19	28.31	8.22	23.83
Max depth (m)	0.65	0.18	0.77	0.815	0.655	0.18	0.755	0.79	1.7	0.48
Avg pool depth (m)	0.39	0.11	0.39	0.46	0.36	0.13	0.46	0.48	0.85	0.32
Max. curr. velocity (m/s)	0.78	0.61	0.97	0.00	0.47	0.65	0.71	0.73	0.67	0.91
Campostoma ornatum	0	0	0	0	226	0	0	0	15	0
Cyprinella lutrensis	1623	23	1518	321	267	148	257	54	462	374
Cyprinus carpio	0	0	0	0	0	0	1	3	0	0
Hybognathus amarus	0	0	12	0	0	0	1	2	13	20
Macrhybopsis aestivalis	7	0	13	0	0	0	0	45	41	19
Notropis braytoni	28	0	246	202	81	0	16	294	210	607
Notropis chihuahua	0	0	0	6	25	0	0	0	52	1
Pimephales promelas	1	0	0	1	3	0	0	0	0	0
Rhinichthys cataractae	0	0	3	0	0	0	0	0	0	6
Carpiodes carpio	19	0	0	22	0	0	0	23	40	9
Cycleptus elongatus	0	0	0	0	0	0	3	40	0	0
Astyanax mexicanus	0	0	0	0	9	2	3	7	1	0
Ictalurus furcatus	0	0	0	0	0	0	0	1	0	0
Ictalurus punctatus	3	0	0	6	0	0	0	1	20	0
Pylodictis olivaris	0	0	0	1	0	0	0	0	0	2
Menidia beryllina	0	0	0	0	0	0	0	0	0	1
Gambusia affinis	3	46	0	0	0	42	85	14	0	0
Fundulus zebrinus	0	0	0	12	85	143	14	0	8	0
Lepomis cyanellus	0	0	0	0	0	0	0	0	0	1

Table 8. Sampling date, measured environmental variables, and fish species collected in long-term monitoring sites in June 2011. Sample numbers correspond to Figure 1.

Site	1	2	3	4	5	6	7	8	9	10
Date	6/6/11	6/6/11	6/7/11	6/8/11	6/8/11	6/8/11	6/8/11	6/8/11	6/7/11	6/7/11
Environmental variable										
Water temp (C°)	30.82	29.69	22.97	23.27	25.27	37.78	30.56	33.65	30.31	29.67
pH	7.58	7.7	8.01	7.76	7.4	8.16	7.62	7.85	8.09	8.07
Dissolved oxygen (mg/L)	5.14	5.35	7.84	3.35	3.43	10.02	7.7	8.67	12.47	8.54
Conductivity (µS/cm)	1892	678	1545	2046	2000	876	1378	1357	1072	1633
Mean turbidity (NTU)	52.59	6.44	95.39	9.58	7.13	5.49	31.63	41.47	16.11	60.69
Total dissolved solids (mg/L)	943	339	772	1023	1000	437	689	679	539	817
Salinity	0.95	0.33	0.78	1.04	1.02	0.42	0.68	0.67	0.53	0.82
Mean chlorophyll-a (µg/L)	12.14	1.52	9.98	3.72	1.01	2.83	6.26	6.30	4.30	8.64
Boulder (%)	0.17	0.00	0.33	0.11	0.05	0.00	0.29	0.06	0.00	0.05
Cobble (%)	0.61	0.00	0.11	0.11	0.10	0.00	0.43	0.33	0.00	0.48
Gravel (%)	0.11	0.06	0.11	0.50	0.52	0.56	0.00	0.44	0.11	0.24
Sand (%)	0.06	0.78	0.06	0.17	0.29	0.17	0.14	0.11	0.00	0.19
Mud (%)	0.06	0.17	0.39	0.11	0.05	0.28	0.14	0.06	0.78	0.05
Bedrock (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00
Pool length (m)	296	100	200	42	70	150	158	178	201	279
Mean site width	41.33	6.03	21.90	2.77	3.77	5.01	31.19	37.67	9.38	31.86
Max depth (m)	0.63	0.16	1.6	0.52	0.53	0.13	0.83	0.77	1.33	0.66
Avg pool depth (m)	0.44	0.09	0.52	0.23	0.21	0.09	0.44	0.34	0.62	0.39
Max. curr. velocity (m/s)	0.88	0.23	1.09	0	0.17	0.62	0.77	0.832	0.563	0.909
Lepisosteus osseus	2	0	1	0	0	0	0	6	0	2
Dorosoma cepedianum	3	0	2	0	0	0	64	36	0	2
Campostoma ornatum	0	0	0	0	315	0	0	0	101	0
Cyprinella lutrensis	2735	5	2448	354	157	1475	1799	757	1508	1463
Cyprinus carpio	121	0	132	0	0	4	12	355	0	131
Hybognathus amarus	0	0	8	1	0	0	0	2	6	6
Macrhybopsis aestivalis	3	0	10	0	0	0	47	34	4	33
Notropis braytoni	19	0	195	439	91	614	343	300	1920	426
Notropis chihuahua	0	0	0	1	87	0	0	0	247	0
Pimephales promelas	2	0	9	1	0	0	0	0	23	0
Rhinichthys cataractae	1	0	1	0	0	0	0	0	0	7
Carpiodes carpio	420	0	171	41	1	68	18	192	5	159
Cycleptus elongatus	0	0	0	0	0	0	2	3	0	16
Astyanax mexicanus	5	0	3	0	17	341	86	14	8	0
Ictalurus furcatus	0	0	0	0	0	0	0	1	4	1
Ictalurus punctatus	0	0	7	1	0	0	8	9	21	1
Pylodictis olivaris	0	0	0	1	0	0	0	1	0	2
Gambusia affinis	129	2699	568	0	0	86	186	189	11	37
Fundulus zebrinus	0	0	0	108	366	166	2	1	235	3
Lepomis cyanellus	0	0	0	1	0	0	0	0	0	0
Lepomis megalotis	0	0	24	0	0	0	25	92	0	1
Micropterus salmoides	1	0	0	0	0	0	0	0	0	0
Oreochromis aurea	0	0	0	0	0	0	0	1	0	0

Table 9. Sample information, measured environmental variables, and fish species collected in regional sites in 2009-2010. Sample numbers correspond to Figure 1.

	11	12	13	14	15	16	17	18	19	20	21
Sample Information											
Date	10/12/09	10/12/09	7/21/10	7/22/10	7/22/10	8/10/10	8/10/10	8/11/10	8/11/10	8/11/10	8/11/10
GPS (North)	30.1450	30.1494	29.8913	29.6742	29.8144	29.8102	29.6578	29.5810	29.5548	29.5788	29.3175
GPS (West)	103.6093	103.5656	104.0151	104.1723	104.3069	103.6468	103.6487	103.6075	103.6307	103.6080	103.5518
Environmental variables											
Elevation (ft)	4636	4739	3803	3158	3801	3643	3358	3161	3137	3165	2483
Water temp (C°)	19.1	18.42	30.2	30.1	28.49	25.54	30.04	26.68	30.58	31.34	32.47
pH	7.94	8.02	7.53	7.62	7.72	9.37	8.8	8.54	8.5	8.79	8.13
Dissolved oxygen (mg/L)	4.25	5.17	4.37	2.64	6.54	8.05	5.35	3.61	4.52	5.39	5.8
Conductivity (uS/cm)	410	570	1071	701	467	278	305	167	485	300	431
Mean turbidity (NTU)	2.70	3.76	6.91	9.19	7.99	55.62	>200	101.88	>200	81.15	26.51
Mean chlorophyll-a (µg/L)	1.70	2.13	2.23	3.45	2.75	23.65	15.97	7.62	17.21	5.20	1.85
Boulder (%)	0	10	0	10	0	5	5	0	1	10	5
Cobble (%)	50	5	10	40	50	0	5	5	1	15	5
Gravel (%)	40	5	90	50	50	0	0	5	1	5	30
Sand (%)	0	0	0	0	0	0	0	30	1	40	5
Mud (%)	0	0	0	0	0	95	90	60	96	30	30
Bedrock (%)	10	80	0	0	0	0	0	0	0	0	25
Pool length (m)	100	70	5	15	60	50	100	100	122	50	70
Mean site width (m)	6.32	3.28	1.5	2.5	3.5	4	5.5	10	15	8	5.5
Max depth (m)	0.7	1	0.43	0.28	0.4	0.86	0.64	1.4	0.22	1.25	0.79
Mean pool depth (m)	0.4	0.5	0.25	0.2	0.25	0.45	0.35	0.5	0.15	0.45	0.4
Max. current velocity (m/s)	0.75	0.66	.	0	.	0	0	0	0	0	0
Species											
Campostoma ornatum	0	0	830	557	0	0	0	0	0	0	1
Cyprinella lutrensis	0	0	8	56	0	427	86	469	10	479	297
Dionda episcopa	0	0	0	7	145	0	0	0	0	0	0
Notemigonus crysoleucas	0	0	1	0	0	0	0	0	0	0	0
Notropis braytoni	0	0	0	0	0	0	0	0	0	0	155
Notropis chihuahua	0	0	0	0	0	0	0	0	0	0	30
Carpiodes carpio	0	0	0	0	0	0	20	22	0	23	19
Astyanax mexicanus	0	0	0	0	0	0	0	0	0	0	3
Ictalurus furcatus	0	0	0	0	0	0	0	0	0	0	3
Ictalurus punctatus	0	0	0	0	0	0	0	0	0	0	16
Pylodictis olivaris	0	0	0	0	0	0	0	0	0	0	2
Fundulus zebrinus	1	32	0	0	0	0	0	1	1	10	60
Lepomis cyanellus	58	58	13	0	3	891	74	78	0	172	0
Micropterus salmoides	14	0	0	0	0	0	0	0	0	0	0

Table 10. Sample information, measured environmental variables, and fish species collected in regional sites in 2010-2011. Sample numbers correspond to Figure 1.

	24	25	26	27	28	29	30	31	32	33	
Sample Information											
Date	10/15/2010	10/16/2010	11/20/2010	12/17/2010	12/18/2010	12/18/2010	1/21/2011	2/18/2011	2/19/2011	4/29/2011	4/2[illegible]
GPS (North)	29.32895	29.16791	29.17108	29.81941	29.19916	29.73215	29.20617	29.29773	29.38689	30.10524	29
GPS (West)	103.55730	103.61298	103.60998	104.30654	103.60616	104.05291	103.60387	103.54802	103.1097	103.593	103.
Environmental variables											
Elevation (ft)	2505	2165	2166	3935	2211	3596	2241	2452	2877	4733	3
Water temp (C°)	24.06	19.81	19.16	16.62	20.69	9.53	24.2	21.68	28.26	20.54	2[illegible]
pH	7.7	8.39	8.22	7.66	8.26	8.02	7.6	7.6	8.52	7.95	8
Dissolved oxygen (mg/L)	5.3	7.15	7.2	2.29	12	2.71	5.32	4.94	7.25	3.97	5
Conductivity (µS/cm)	1119	940	1006	334	911	294	877	1675	1232	380	7
Mean turbidity (NTU)	14.47	13.92	14.28	4.70	11.02	18.57	4.83	8.56	6.71	3.98	17
Mean chlorophyll-a (µg/L)	1.10	2.35	14.78	0.43	2.59	1.88	0.11	1.49	1.97	0.58	1[illegible]
Boulder (%)	22	0	0	0	0	0	6	0	0	28	
Cobble (%)	22	0	6	0	11	0	28	0	0	28	
Gravel (%)	50	78	83	56	28	39	33	6	6	33	
Sand (%)	6	17	11	33	6	50	11	0	94	6	
Mud (%)	0	6	0	11	56	11	22	89	0	6	
Bedrock (%)	0	0	0	0	0	0	0	6	0	0	
Pool length (m)	15	20	127	13	17	44	89	68	100	20	[illegible]
Mean site width (m)	3.08	5.53	7.77	1.93	3.42	3.52	6.75	3.33	1.96	7.25	1[illegible]
Max depth (m)	0.68	1.10	0.77	0.73	0.36	1.00	0.61	0.76	0.34	1.10	1
Mean pool depth (m)	0.54	0.69	0.43	0.55	0.27	0.45	0.34	0.26	0.18	0.71	0
Max. current velocity (m/s)	0.33	0.40	0.67	0.00	1.00	0.00	0.51	0.00	0.34	0.00	0

Table 10. Continue.

	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Species														
Dorosoma cepedianum	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Camposioma ornatum	4	0	0	0	3	2	103	0	0	0	0	0	0	33
Cyprinella lutrensis	22	87	104	0	43	475	244	89	0	0	360	145	856	270
Cyprinus carpio	0	1	3	0	0	0	0	0	0	0	0	0	0	0
Dionda episcopa	0	0	0	890	0	0	0	0	0	0	0	0	0	0
Hybognathus amarus	0	0	21	0	0	0	11	0	0	0	0	0	0	0
Macrhybopsis aestivalis	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Notropis braytoni	18	296	60	0	6	0	333	0	0	0	0	27	9	304
Notropis chihuahua	1	0	0	0	3	0	33	0	0	0	0	3	15	22
Pimephales promelas	0	0	0	0	0	0	0	0	0	0	16	10	16	0
Capiodes carpio	8	4	28	0	0	0	73	8	0	0	17	229	56	0
Astyanax mexicanus	17	2	0	0	1	0	17	0	0	0	0	0	8	0
Ictalurus punctatus	1	0	9	0	0	0	3	0	0	0	8	0	6	0
Pylodictis olivaris	0	0	0	0	0	0	0	0	0	0	0	4	7	0
Gambusia affinis	0	65	45	0	0	0	27	0	0	0	0	0	0	0
Fundulus zebrinus	0	2	0	0	146	0	10	99	37	0	15	5	54	426
Lepomis cyanellus	0	0	0	0	0	34	0	0	0	20	34	25	8	0
Lepomis macrochirus	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Micropterus salmoides	0	0	0	0	0	0	0	0	0	1	0	0	0	0

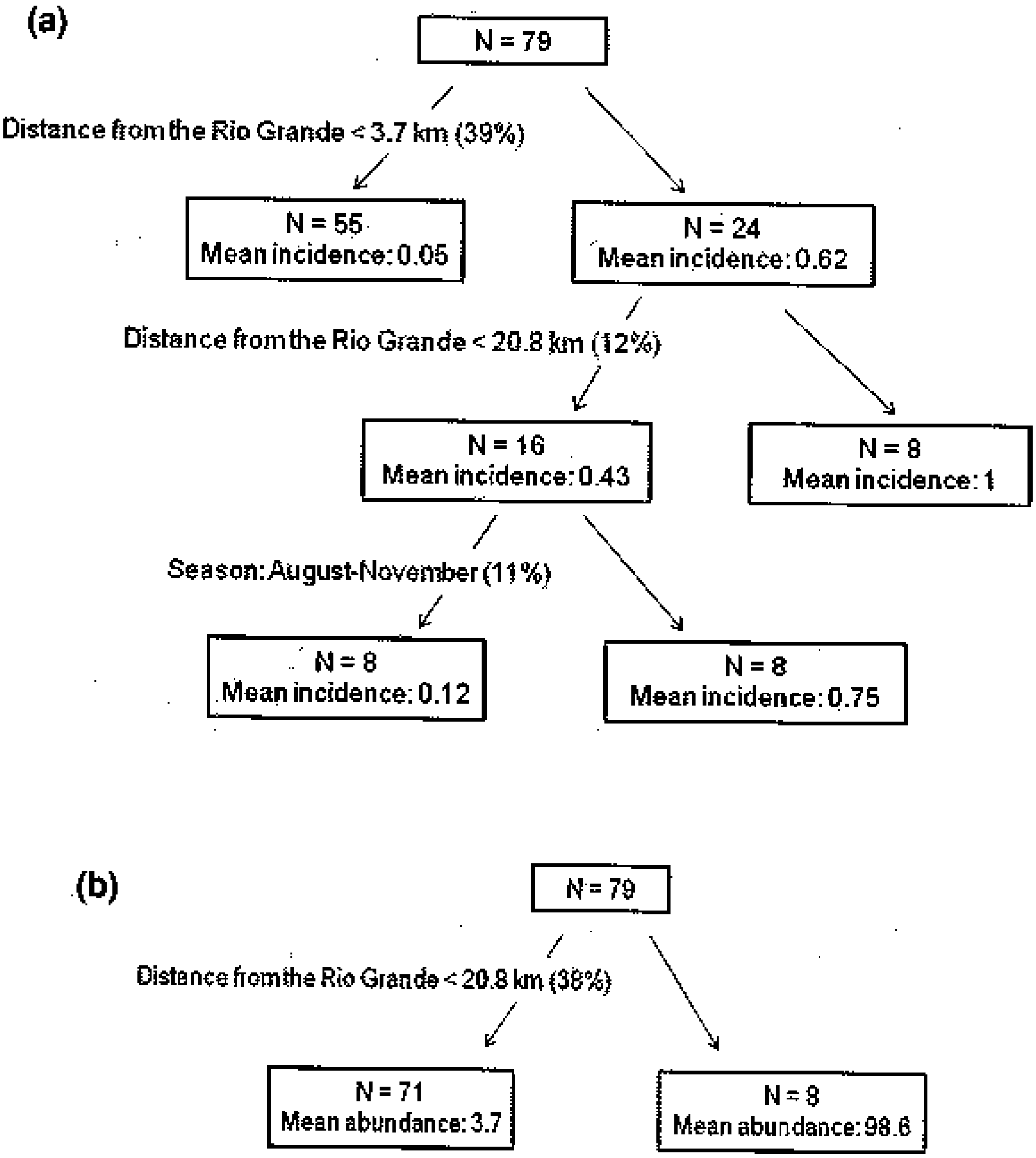

Figure 2. Results of CART for a) incidence and b) abundance of *C. ornatum* collected in the 10 monitoring sites in 2009-2011 (total 79 samples). The numbers in the parentheses indicate the variation (%) explained by the environmental variables.

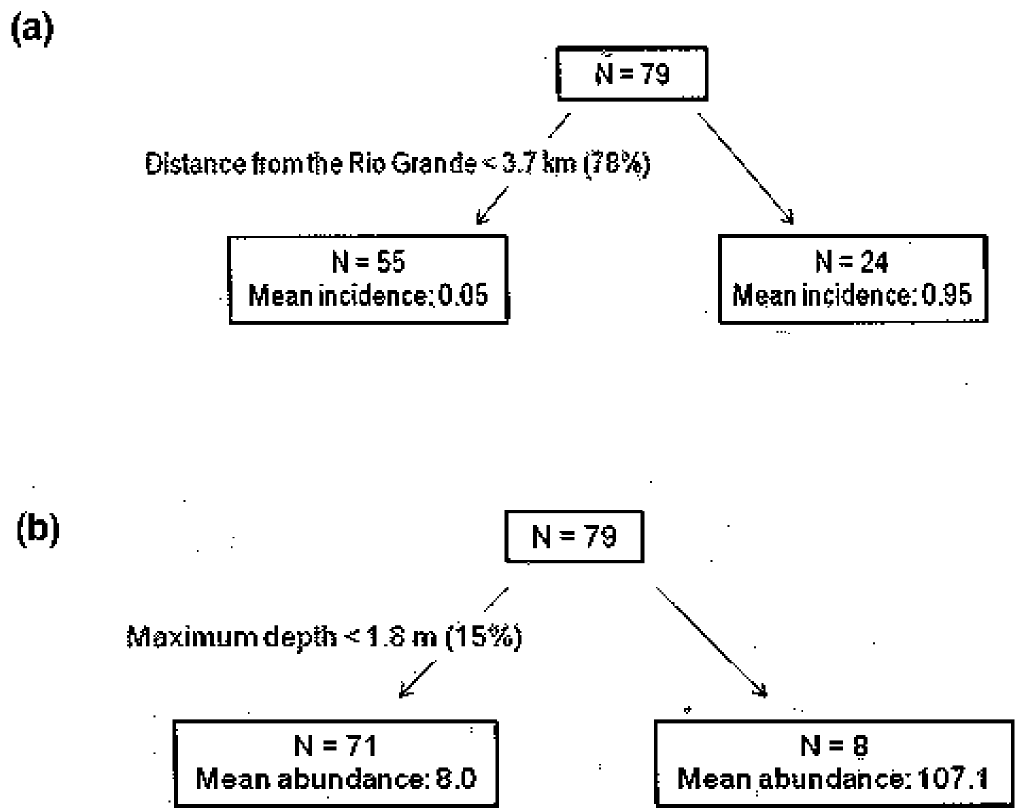

Figure 3. Results of CART for a) incidence and b) abundance of *N. chihuahua* collected in the 10 monitoring sites in 2009-2011 (total 79 samples). The numbers in the parentheses indicate the variation (%) explained by the environmental variables.

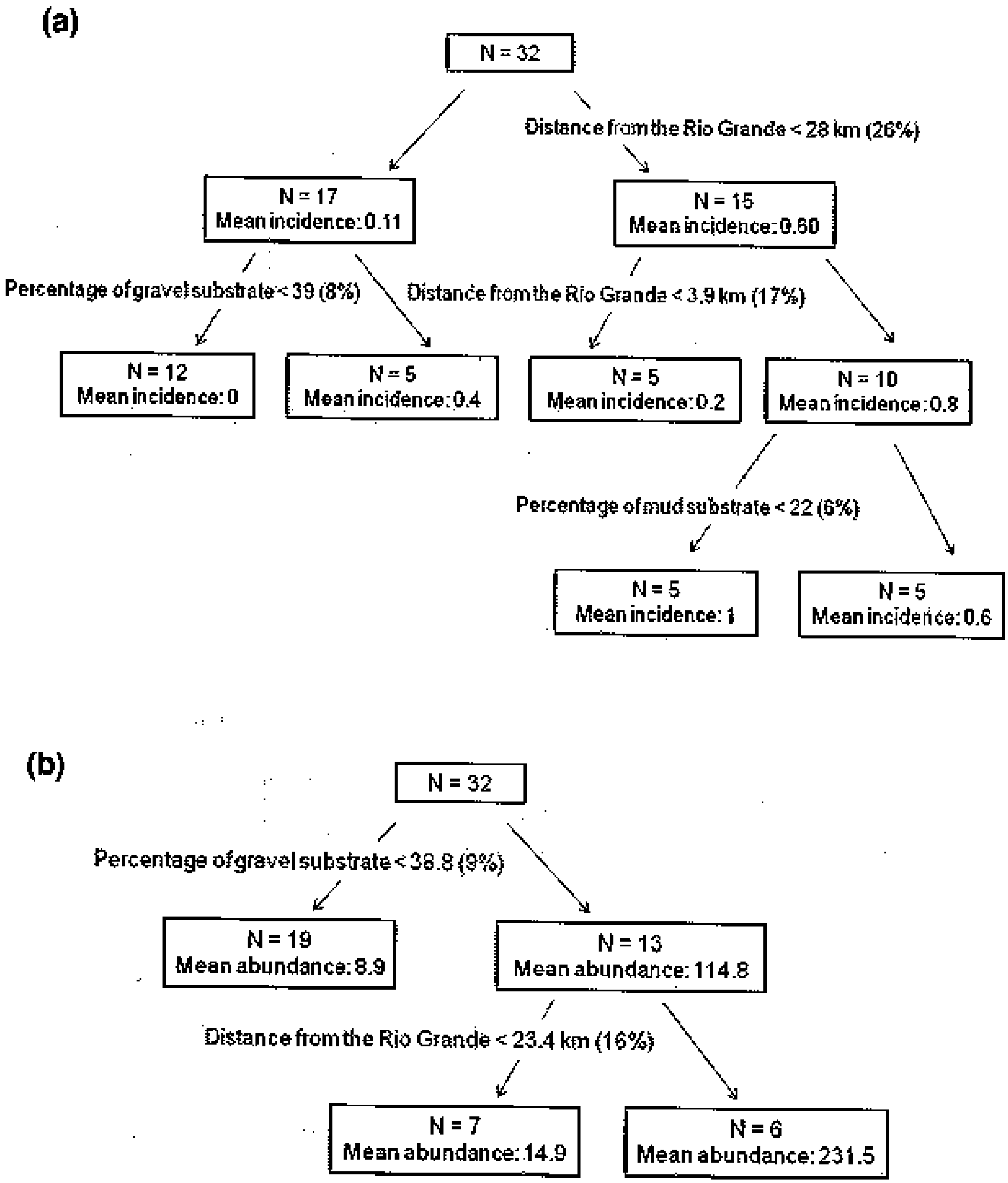

Figure 4. Results of CART for a) incidence and b) abundance of *C. ornatum* collected in the 32 tributary localities in 2009-2011. The numbers in the parentheses indicate the variation (%) explained by the environmental variables.

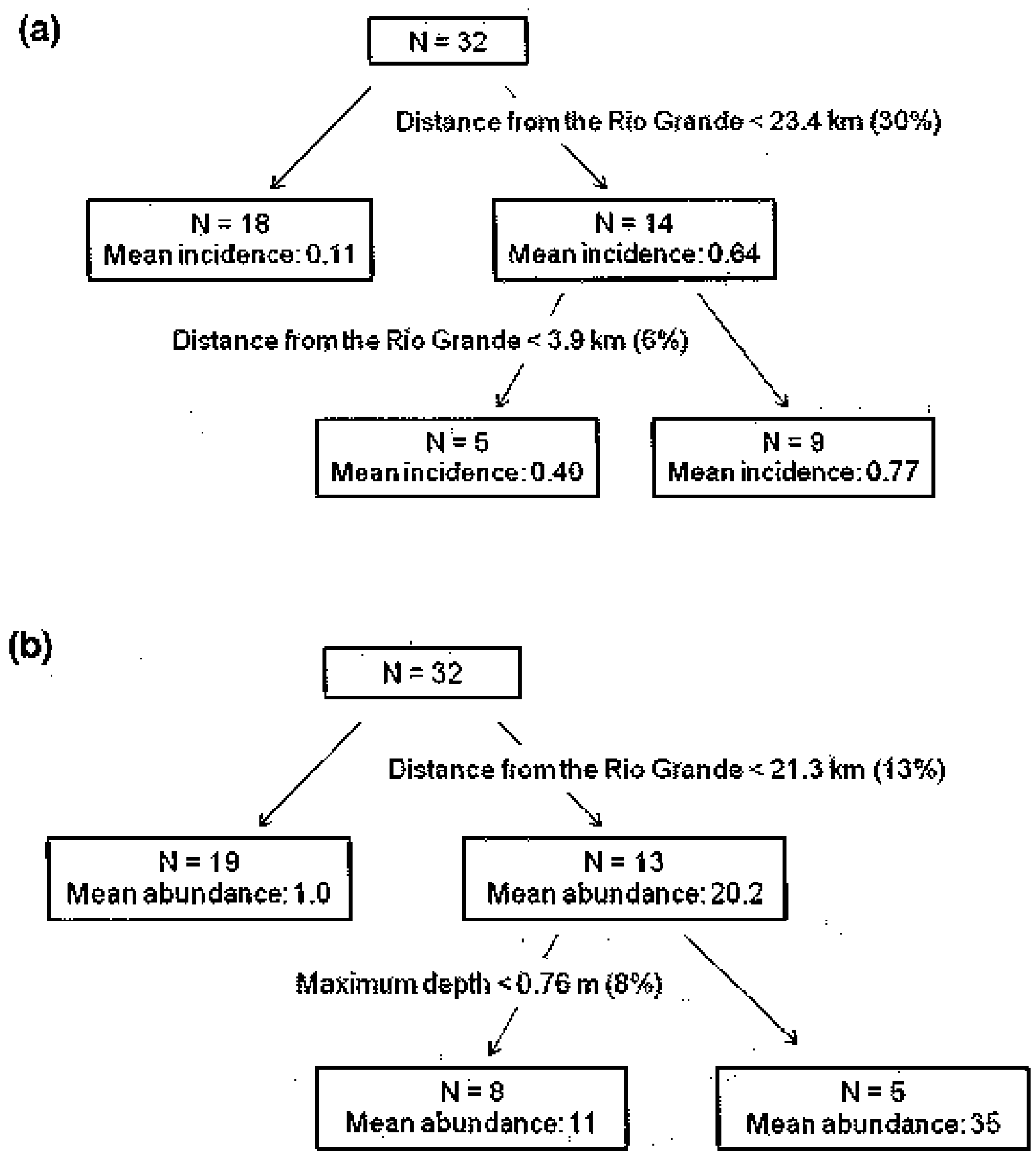

Figure 5. Results of CART for a) incidence and b) abundance of *N. chihuahua* collected in the 32 tributary localities in 2009-2011. The numbers in the parentheses indicate the variation (%) explained by the environmental variables.

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