Managing Native Fish Species and Invertebrates in Desert Sinkholes

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Abstract

When relating fish populations to environmental variables, numerous studies have utilized a multiple-lake approach. These studies have largely been performed in north-temperate locations. Although some multi-lake studies have been conducted on tropical lakes, information on other warmwater fish communities, like desert species, is lacking due to scarce water resources and the rarity of multiple lakes within a relatively confined geographic region. We hypothesized that fish abundance is primarily determined by abiotic factors, as these can have extreme values in desert environments. We investigated abundance (mark-recapture and catch-per-unit-effort estimates) and condition (length-weight relationship) in 23 sinkholes in New Mexico and correlated those factors to physical, chemical, and biological factors. The sinkholes are located within a few square kilometers on Bitter Lake National Wildlife Refuge and provide habitat for 6 native fish species. Despite their proximity, the sinkholes differ greatly from each other in terms of abiotic factors. For example, total depth varies between 0.5 and 15 m, Secchi depth lies between 0.25 and 4 m, and salinity between 4 and 120 ppt. Using regression analyses, we found that fish abundance and condition are primarily influenced by biological factors, particularly the presence of other fish species and chlorophyll a.

Introduction

The Pecos River of New Mexico is a typical western U.S. river in that it has been severely affected by human activity and whose fish community has suffered as a result. Human developments to the region have greatly altered the structure and hydrologic regime of the river. The constructions of several dams along the Pecos have altered both the flow and thermal regimes. Reservoirs attenuate spring snowmelt and rainfall events, which now nearly eliminate natural cyclical flooding, and leave seasonally-desiccated river reaches (Propst 1999). Water releases from reservoirs, depending on the depth at which water is released, can substantially increase or decrease water temperatures downstream. Sediment that would normally wash downstream is now collected behind the dams. Finally, salt cedar was intentionally planted in the 1930s to stabilize the Pecos River's banks (Tashjian 2003). This not only reduced flooding but incised the river to create a narrow channel with poor-quality fish habitat. Along with habitat alteration, introductions of non-native zoological species are a primary reason for the decline of the endemic fish populations in the southwestern U.S. Non-native fish species affect native fish species via predation and competition for food and habitat.

Pecos gambusia (*Gambusia nobilis*) and Pecos pupfish (*Cyprinodon pecosensis*) are examples of native species whose distribution has been severely reduced as a result of habitat alteration and non-native fish introductions. Both species appear on the New Mexico Species of Greatest Conservation Need list and are considered "Critically Imperiled" on a State and National Level (New Mexico Department of Game and Fish 2006). Pecos gambusia was formerly found as far north in the Pecos River as Fort Sumner, inhabiting 600 river miles but today is mainly restricted to sinkholes and springs on the west side of the Pecos River in Chavez (east of Roswell) and Eddy (south of Carlsbad) counties (Echelle and Echelle 1980, Cowley and Sublette 1987) (Fig. 1). Pecos gambusia is also outcompeted by and hybridizes with Western mosquitofish (*Gambusia affinis*) (Bednarz 1979, Echelle and Echelle 1980), does not coexist with predatory green sunfish (*Lepomis cyanellus*) and will not survive in water with hardness above 5 g L^{-1} $CaCO_3$ (Bednarz 1979). It is a federally endangered species.

The Pecos pupfish historically occurred in the mainstream Pecos River from Roswell, New Mexico, occupying 400 river miles (Fig. 1). It also resided in small tributaries to the Pecos River, springs, and sinkholes and is most abundant in highly saline habitats composed of relatively few species (Echelle and Echelle 1978). The Pecos pupfish is now a state-threatened species (Sublette et al. 1990, New Mexico Department of Game and Fish 2006) due to habitat alteration and the introduction of nonnative sheepshead minnow (*Cyprinodon variegatus*), most likely caused by bait bucket releases (Brooks and Wood 1988). Not only must the two species compete for resources, but sheepshead minnow also hybridizes with Pecos pupfish (Echelle et al. 1987). The only pure populations of Pecos pupfish still found in significant concentration are contained within sinkholes, oxbow lakes, and impoundments of Bitter Lake National Wildlife Refuge (BLNWR) (Brooks and Wood 1988).

Pecos pupfish occur in 21 of the sinkholes and Pecos gambusia in eight sinkholes (Brooks and Wood 1988, Hoagstrom and Brooks 1999, Swaim and Boeing in prep.). However, population abundances vary greatly among sinkholes (Hoagstrom and Brooks 1999), and the causes for this have yet to be determined. Abiotic variables vary greatly among sinkholes (Hoagstrom and

Brooks 1999, Boeing and Swaim in prep.), and these differences may help explain the variability of abundances of the fish species as well as invertebrates (zooplankton, benthos) found on BLNWR. In summer 2006, we observed on 41 sinkholes on BLNWR. These records included measurements of both biotic (Pecos pupfish fish abundance and condition; benthos – samples are still being counted; zooplankton – samples are still being counted; chlorophyll a) and abiotic (temperature-, oxygen-, pH-, salinity-, and turbidity profiles, total phosphorus, hardness) conditions. Change in water levels, salinity, turbidity, pH, oxygen, temperature was compared to data collected in summer 2005. We then used regression analysis to determine which environmental factors most influence pupfish abundance and condition.

Materials and Methods

Fish

Small-bodied fish species, which comprise all species in sinkholes at BLNWR, are most effectively captured with minnow traps (Jackson and Harvey 1997). We carried out a pilot study on 4 weekends in April and May 2006 to determine the number of traps and locations necessary to adequately sample the sinkholes (Swaim and Boeing, unpublished data). We found distinct separation of fish species depending on depth the traps were located and only few individuals were caught in our "offshore stations". Therefore, we set minnow traps every 5 m along the shoreline at 0.5 m below the surface, at Secchi depth and 0.5 m above the sediment. Shallow sinkholes and those with high water clarity only had one or two traps per station. We used 120 plastic minnow traps to capture fish. Twenty-three sinkholes (eighteen sinkholes were fishless) were surveyed between July 20 and August 5, 2007 on two consecutive days. By that time all fish had already spawned and fish were moving around freely and were not guarding nests. Minnow traps were set in the evenings and retrieved the next morning. On the first day, all captured fish were identified and counted and then marked by clipping the top of their caudal fin. On the second day, captured fish were identified and counted as marked or unmarked. Additionally, we took total length and weight of up to 100 individuals per species.

Lower trophic level biotic and abiotic parameters

We used a Hydrolab (Hach Environmental) to obtain temperature, oxygen, pH, salinity and turbidity profiles in 1 m intervals of each sinkhole. We took water samples with a vertical point water sampler in 1 m intervals and combined them in a bucket for each sinkhole. The water sample were mixed and 500 mL was fixed in a plastic sample bottle with 1 mL concentrated H_2SO_4 for total phosphorus analysis by the Soil, Water and Agricultural Testing Laboratory (SWAT-Lab) (http://swatlab.nmsu.edu/). A second sample bottle was filled for water hardness ($CaCO_3$). All sample bottles were kept at 4 ˚C until they were handed to the SWAT-Lab. Another 500 mL was filtered with a hand pump onto a GF/F filter. The filter was kept frozen until our return to the laboratory. Filters were then grinded and chlorophyll a extracted in ethanol. Chlorophyll a was measured with a spectrophotometer as an estimate of phytoplankton biomass. To obtain zooplankton samples we performed vertical tows with a zooplankton net (Ø 20 cm, 110 µm mesh). Finally a sediment sample was obtained for benthic organisms. Both zooplankton and benthos were preserved in 90% ethanol and species abundance is being determined in the laboratory under a microscope.

Statistical analyses

Fish abundance was estimated using the Petersen method (Sutherland 2003). Often, not enough fish were re-captured to be able to calculate an accurate population estimate. Therefore, we also used catch per unit effort (CPUE) defined as number of fish caught per trap per hour. The regression between absolute population estimate and CPUE was tight ($r^2 = 0.84$). Fish species abundance and composition in response to environmental factors was analyzed using a stepwise regression.

Results and Discussion

Abiotic parameters varied tremendously among sinkholes (Table 1).

Table 1: Range in abiotic parameters in 41 sinkholes of the middle tract of Bitter Lake National Wildlife Refuge.

Variable	**Range**
Total depth (m)	**0.3 – 14.1**
Secchi depth (m)	**0.1 – 4.7**
Diameter (m)	**7 - 59**
Temperature (°C)	**19.00 – 32.08**
Salinity (ppt)	**3.85 – 121.60**
Turbidity (NTU)	**0.0 – 302.6**
Dissolved oxygen (mg/L)	**0.09 – 21.21**
pH	**6.87 – 9.07**
Total phosphorus (mg/L)	**0.01 – 0.35**
Chlorophyll a (mg/L)	**0.534 – 37.380**

Surprisingly though, abiotic parameters did not influence pupfish abundance and condition but the presence of competitors did (Figs 1 and 2).

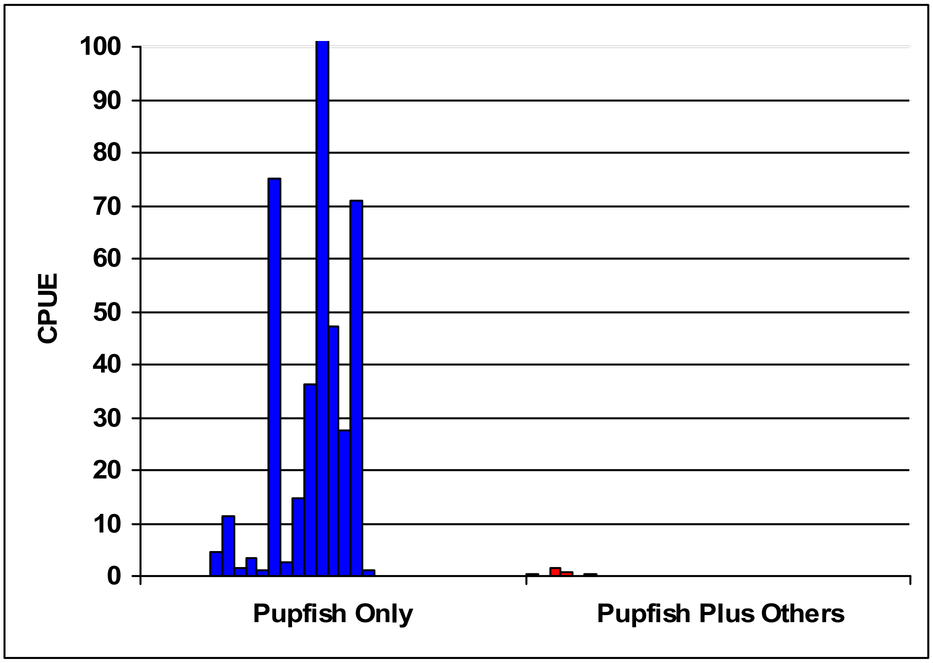

Figure 1: Catch per unit effort of Pecos pupfish in presence and absence of other fish species.

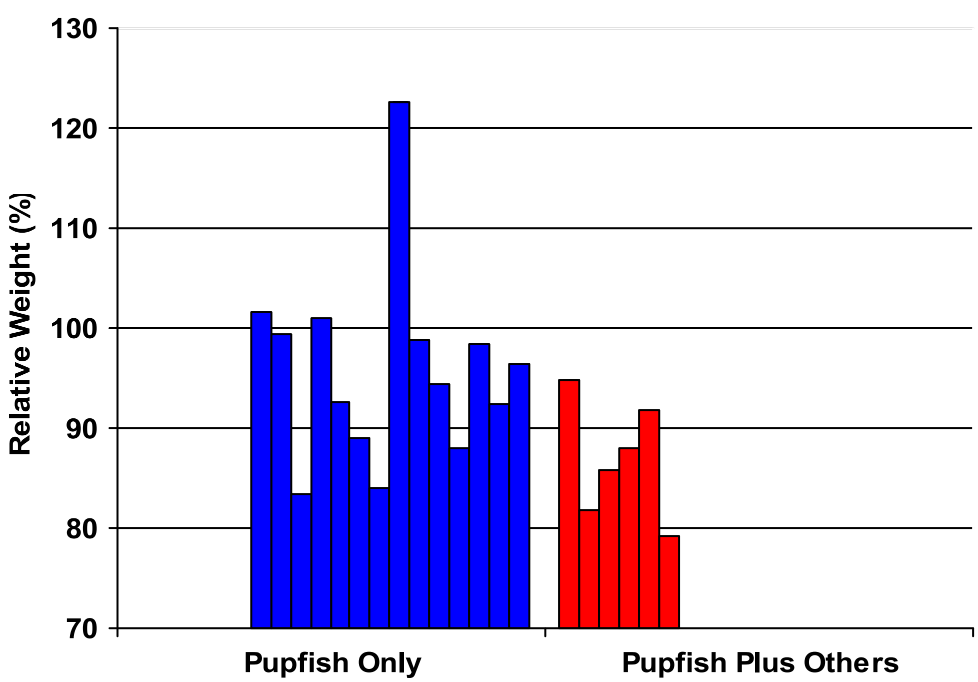

Figure 2: Fish condition (relative weight) of Pecos pupfish in the presence and absence of other fish species.

Catch per unit effort (CPUE) was primarily depend on the presence of other fish species as well as on dissolved oxygen and chlorophyll a and relative weight just on the presence of other fish species.

CPUE = -47.189 – 39.415x_1 + 12.589x_2 + 6.259x_3 ($r^2 = 0.66$)

x_1 = presence of other species
x_2 = dissolved oxygen
x_3 = chlorophyll a

Relative weight = 96.136 – 9.669x_1 ($r^2 = 0.22$)

x_1 = presence of other species

If only sinkholes were considered that only contained Pecos pupfish, CPUE was dependent on sinkhole depth, dissolved oxygen and chlorophyll a. No variable fit into the model for relative weight.

CPUE -55.970 – 7.491x_1 + 20.169x_2 + 6.536x_3 ($r^2 = 0.86$)

x_1 = total depth
x_2 = dissolved oxygen
x_3 = chlorophyll a

In order to manage Pecos pupfish on the Bitter Lake National Wildlife Refuge, we recommend to manage Pecos pupfish and Pecos gambusia in separate sinkholes.

Literature Cited

Bednarz, J.C. 1979. Ecology and status of the Pecos gambusia, *Gambusia nobilis* (Peociliidae), in New Mexico. Southwestern Naturalist 24: 311-322.

Brooks, J.E. and M.K. Wood. 1988. A survey of the fishes of Bitter Lake National Wildlife Refuge, with an historic overview of the game and nongame fisheries. USFWS Special Report, Dexter National Fish Hatchery, Dexter, NM.

Cowley, D.E. and J.E. Sublette. 1987. Distribution of fishes in the Black River drainage, Eddy County, New Mexico. Southwestern Naturalist 32: 213-221.

Echelle, A.A., and A.F. Echelle. 1978. The Pecos River pupfish, *Cyprinodon pecosensis* n. sp. (Cyprinodontidae), with comments on its evolutionary origin. Copeia 1978(4): 569-582.

Echelle, A.A., and A.F. Echelle. 1980. Studies of the Pecos gambusia, *Gambusia nobilis*. USFWS, Albuquerque, New Mexico Endangered Species Rept. No. 10, 73 pp.

Echelle, A.A., A.F. Echelle, and D.V. Edds. 1987. Population structure of four pupfish species (Cyprinodontidae: Cyprinodon) from the Chihuahuan desert region of New Mexico and Texas: allozymic variation. Copeia 1987(3): 668-681.

Hinch, S.G. 1991. Small- and large-scale studies in fisheries ecology: the need for cooperation among researchers. Fisheries 16: 22-27.

Hinch, S.G., and N.C. Collins. 1993. Relationships of littoral fish abundance to water chemistry and macrophyte variables in central Ontario lakes. Canadian Journal of Fisheries and Aquatic Sciences 50: 1870-1878.

Hinch, S.G., N.C. Collins, and H.H. Harvey. 1991. Relative abundance of littoral zone fishes: biotic interactions, abiotic factors, and postglacial colonization. Ecology 72: 1314-1324.

Hoagstrom, C.W. and J.E. Brooks. 1999. Distribution, status, and abundance of the Pecos pupfish, *Cyprinodon pecosensis*. Technical Report No. 2. New Mexico Department of Game and Fish, Santa Fe, New Mexico. 76 pp.

Jackson, D.A. and H.H. Harvey. 1997. Qualitative and quantitative sampling of lake fish communities. Canadian Journal of Fisheries and Aquatic Sciences 54: 2807-2813.

Jackson, D.A., P.R. Peres-Neto, and J.D. Olden. 2001. What controls who is where in freshwater fish communities—the roles of biotic, abiotic, and spatial factors. Canadian Journal of Fisheries and Aquatic Sciences 58: 157-170.

Marshall, T.R., and P.A. Ryan. 1987. Abundance patterns and community attributes of fishes relative to environmental gradients. Canadian Journal of Fisheries and Aquatic Sciences 44(Suppl. 2): 198-215.

Matuszek, J.E. 1978. Empirical predictions of fish yields of large North American lakes. Transactions of the American Fisheries Society 197: 385-394.

Moyle, J.B. 1956. Relationship between the chemistry of Minnesota surface waters and wildlife management. Journal of Wildlife Management 20: 303-320.

New Mexico Department of Game and Fish (NMDGF). 2005. Comprehensive Wildlife Conservation Strategy for New Mexico. http://fws-nmcfwru.nmsu.edu/cwcs/New_Mexico_CWCS.htm.

Prepas, E.E. 1983. Total dissolved solids as a predictor of lake biomass and productivity. Canadian Journal of Fisheries and Aquatic Sciences 40: 92-95.

Propst, D.L. 1999. Threatened and endangered fishes of New Mexico. Technical Report No. 1. New Mexico Department of Game and Fish.

Rago, P.J., and J.G. Wiener. 1986. Does pH affect fish species richness when lake area is considered? Transactions of the American Fisheries Society 115: 438-447.

Rahel, F.J., and J.J. Magnuson. 1983. Low pH and the absence of fish species in naturally acidic Wisconsin lakes: inferences for cultural acidification. Canadian Journal of Fisheries and Aquatic Sciences 40: 3-9.

Rawson, D.S. 1952. Mean depth and the fish production of large lakes. Ecology 33: 513-521.

Robinson, C.L.K., and W.M. Tonn. 1989. Influence of environmental factors and piscivory in structuring fish assemblages of small Alberta lakes. Canadian Journal of Fisheries and Aquatic Sciences 46: 81-89.

Rodriguez, M.A. and W.M. Lewis, Jr. 1997. Structure of fish assemblages along environmental gradients in floodplain lakes of the Orinoco River. Ecological Monographs 67: 109-128.

Rounsefell, G.A. 1946. Fish production in lakes as a guide for estimating production in proposed reservoirs. Copeia 1: 29-40.

Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. Transactions of the American Fisheries Society 94: 214-218.

Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. The fishes of New Mexico. University of New Mexico Press, Albuquerque, 393 pp.

Tejerina-Garro, F.L., R. Fortin, and M.A. Rodriguez. 1998. Fish community structure in relation to environmental variation in floodplain lakes of the Araguaia River, Amazon Basin. Environmental Biology of Fishes 51: 399-410.

Tonn, W.M., and J.J. Magnuson. 1982. Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. Ecology 63: 1149-1166.