The Effects of Habitat Fragmentation on the Yazoo Darter (*Etheostoma raneyi*)

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INTRODUCTION

The Yazoo darter is restricted to headwater streams in the upper Yazoo River drainage. Habitat has been extensively modified (mostly due to flood control projects) and impoundments, channelized stream reaches, and stream incisement have fragmented virtually all streams within the species' range.

The Yazoo darter's restricted range along with habitat degradation and fragmentation within that range puts it at risk of extinction. The species is classified as vulnerable by the Southeastern Fishes Council and American Fisheries Society, and as globally imperiled by the Nature Conservancy.

OBJECTIVES

- Estimate historic and contemporary rates of dispersal between populations
- Estimate historic and contemporary effective population sizes (Ne)
- Detect possible genetic signatures of population declines (bottlenecks)

METHODS

- We collected fin clips from 212 individuals at 17 sites (**Fig. 1**).
- Target sequences were amplified (PCR) using 10 microsatellite markers.
- GENELAND was used to distinguish genetically distinct clusters.
- We grouped all individuals into 11 populations as determined by GENELAND for the following analyses.
- BAYESASS was used to estimate contemporary migration rates.
- MIGRATE was used to estimate historic migration rates and the parameter θ.
- We used the equation $\theta = 4N_e\mu$ (θ = mutation scaled Ne, μ = mutation rate = 5×10^{-4}), to estimate historic Ne.
- We also estimated historic Ne using the single step mutation model (SMM) and the infinite allele model (IAM).
- ONeSAMP was used to estimate contemporary Ne.
- BOTTLENECK was used to detect reductions in populations.
- ARLEQUIN generated M ratios as another method to detect bottlenecks within populations (M-crit = 0.68).

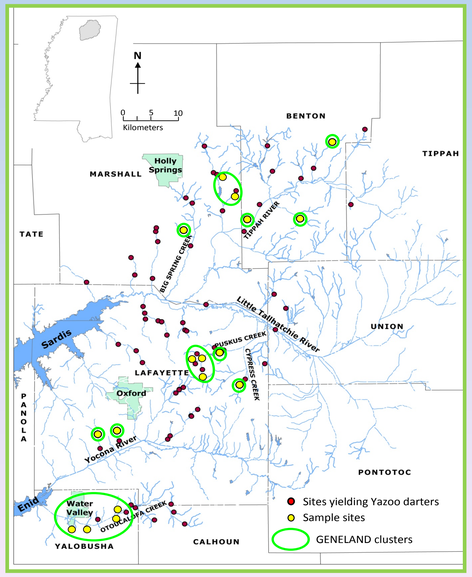

Figure 1. Range of the Yazoo darter showing all known sites with Yazoo darters (red and yellow circles), sample sites (yellow circles), and GENELAND clusters (green circles).

Table 1. Mean (95% C.I.) historic migration rate (migrants per generation, Nm) estimates from MIGRATE across watersheds in the Tallahatchie R. drainage.

Migration Into	Big Spring Creek (1)		Tippah River (2)		Cypress Creek (3)	
	From 2	From 3	From 1	From 3	From 1	From 2
Mean	1.86	1.34	2.28	2.16	1.25	1.32
Lower 95% C.I.	1.56	1.1	1.95	1.86	1.02	1.04
Upper 95% C.I.	2.23	1.62	2.71	2.51	1.51	1.58

Table 2. Mean (95% C.I.) historic migration rate (migrants per generation, Nm) estimates from MIGRATE across watersheds within the Yocona R. drainage.

Migration Into	Otoucalofa Creek (1)		Morris Creek (2)		Taylor Creek (3)	
	From 2	From 3	From 1	From 3	From 1	From 2
Mean	1.62	1.92	1.36	1.76	3.16	4.07
Lower 95% C.I.	1.32	1.69	1.16	1.52	2.64	3.44
Upper 95% C.I.	1.85	2.18	1.59	2.04	3.77	4.83

Table 3. Mean (95% C.I.) contemporary migration rate (migrants per generation, Nm) estimates from BAYESASS across watersheds in the Tallahatchie R. drainage.

Migration Into	Big Spring Creek (1)		Tippah River (2)		Cypress Creek (3)	
	From 2	From 3	From 1	From 3	From 1	From 2
Mean	0.55	0.32	0.83	0.42	0.44	0.62
Lower 95% C.I.	0.004	0.004	0.008	0.006	0.005	0.005
Upper 95% C.I.	2.7	1.65	3.64	1.87	1.94	2.83

Table 4. Mean (95% C.I.) contemporary migration rate (migrants per generation, Nm) estimates from BAYESASS across watersheds within the Yocona R. drainage.

Migration Into	Otoucalofa Creek (1)		Morris Creek (2)		Taylor Creek (3)	
	From 2	From 3	From 1	From 3	From 1	From 2
Mean	0.66	1.44	0.017	0.16	0.273	0.33
Lower 95% C.I.	0.01	0.105	0.001	0.001	0.002	0.002
Upper 95% C.I.	2.75	4.59	0.71	0.67	1.21	1.56

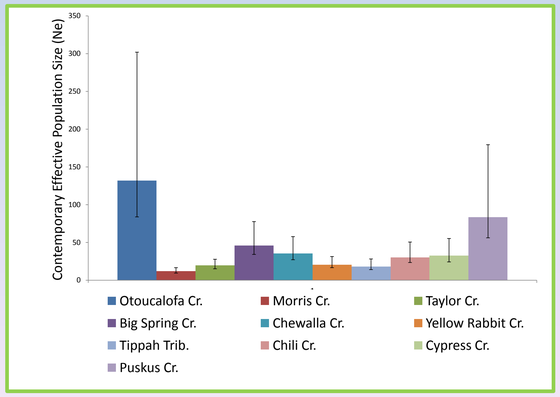

Figure 2. Estimates (95% C.I.) of contemporary Ne per population (ONeSAMP).

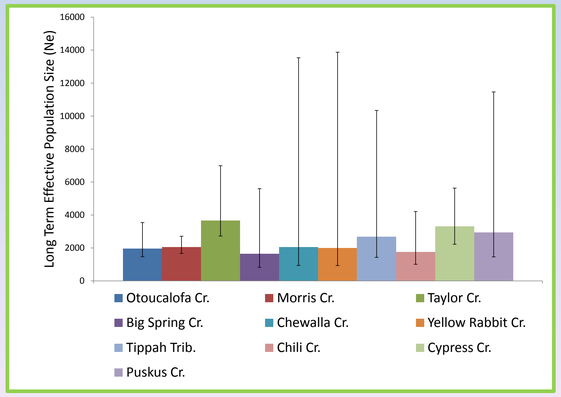

Figure 3. Mean (95% C.I.) historic Ne estimates per population (SMM & IAM models, MIGRATE).

RESULTS

- Historical dispersal is indicated among watersheds within both major river drainages (**Tables 1, 2**).
- Contemporary estimates of dispersal are significantly lower among watersheds within the Tallahatchie R. drainage ($t = 7.18$, $df = 5$, $p < 0.0004$) (**Table 3**), the Yocona R. drainage ($t = 3.63$, $df = 5$, $p < 0.008$) (**Table 4**).

- ONeSAMP recovered surprisingly low estimates of contemporary Ne for all populations (**Fig. 2**).
- Estimates of historic Ne (**Fig. 3**) were significantly higher than contemporary Ne (paired t-test, $t = 10.61$, $n = 10$, $df = 9$, $p < 0.0001$).
- Confidence intervals for contemporary and historic Ne do not overlap.

- Three of 11 populations were significant (adjusted $\alpha = 0.017$) for population size reductions (Wilcoxon test, in BOTTLENECK): Chili Creek ($p < 0.012$), Tippah River Tributary ($p < 0.01$), and Puskus Creek ($p < 0.001$).
- M ratios indicate that all populations have ratios ≤0.5 and upper 95% C.I. estimates ≤0.6, well below the critical M ratio value of 0.68 (**Fig. 4**).

CONCLUSIONS

- Alteration and fragmentation of habitat has led to a severe decline in dispersal among headwater streams.
- There have been severe declines in Ne.
- Declines in Ne has been drastic enough to leave genetic signatures of bottlenecks in all populations.
- Estimates of contemporary Ne for all populations of Yazoo darters are low enough to cause concern for their long-term persistence.

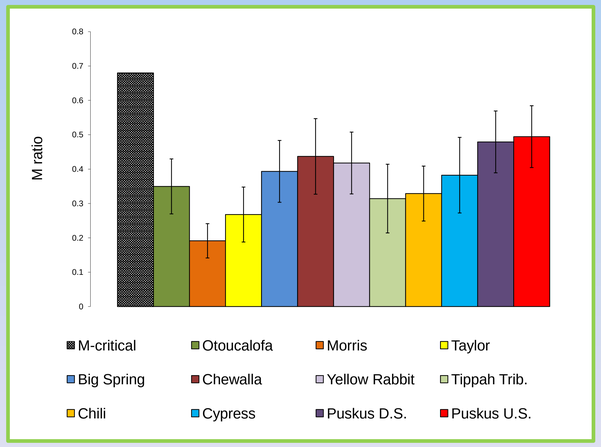

Figure 4. M ratios (95% C.I.) by population (M-crit. = 0.68)

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