Source-sink dynamics in a seasonally fragmented landscape

J.W. Love[1,3], C.M. Taylor[1,4], and M.L.Warren[2]

Abstract and Key Points:

Seasonal drought in intermittent streams may adversely affect assemblage diversity and fish populations. We explored this hypothesis using data collected from upper tributaries of the Alum Fork of the Saline River drainage (central Arkansas) from July to October, 2003 (Fig. 1). These tributaries are hydrologically dynamic (Fig. 2) with pools that shrink and become isolated during summer. Principle components analysis indicated that most habitat variation during summer was related to changes in pool size (Table 1), which were usually more dramatic upstream (Fig. 3). Despite significant reductions in pool size over time (Fig. 4), we found that pool drying had little effect on species richness (Figs. 5 and 6), but significantly influenced community dynamics (Fig. 7). We calculated extinction rate (ER), immigration rate (IR), and population growth rate (λ) and classified sites into three main groups of communities: sources (high I, low E, λ >> 1.0), sinks (low I, high E, λ < 1.0), and transitional meta-communities (moderate I, low E, λ > 1.0; Fig. 8). Summer drying of pools resulted in an increase in the number of sinks which led to higher community nestedness at the end of summer (Fig. 9). Our data generally support a hybrid source-sink and meta-population approach toward understanding extinction and recolonization processes in intermittent streams.

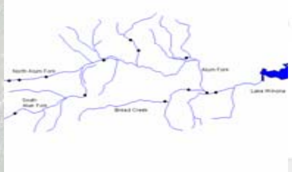
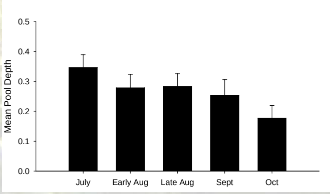


Figure 1:(Above) Map of 13 pools surveyed from the Alum Fork of the Saline River (central Arkansas) during summer 2003. Pools dried throughout summer.

SOUTH ALUM FORK SITE

Variable	PC1	PC2	PC3
CV volume	0.93	0.03	0.09
CV pH	0.88	0.31	-0.18
CV depth	0.86	0.02	0.19
CV D.O	0.84	0.34	-0.34
CV spec. cond.	0.83	0.31	-0.11
D.O.	-0.76	-0.06	0.36
CV turbidity	0.68	0.01	0.48
pH	-0.67	-0.14	0.26
Turbidity	0.63	-0.51	0.40
Distance	0.57	-0.68	0.68



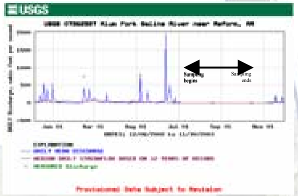


Figure 2: (Above) Flow dynamics within the Alum Fork of the Saline River (central Arkansas). Blue line illustrates daily mean discharge between 6 Dec 2002 and 30 Nov 2003. Arrow covers dates of study. (Left) Photos of a study site in July and October; note the reduction in pool size.

Table 1: (Left) Principle components analysis (PCA) of habitat data collected from sites occurring in the Alum Fork of the Saline river (central Arkansas; summer, 2003). Three principle components explained approximately 66% of the variation among habitats. The majority of habitat variation described hydrological variation. The second and third components described habitat variation related to pool position and chlorophyll *a* content, respectively.

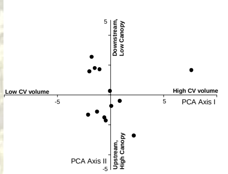


Figure 3: (Above) Ordination from PCA showing that downstream pools generally exhibited the smallest hydrological variation.

Figure 4: (Left) Hydrological variation was described by significant reductions in pool size across summer (repeated measures ANOVA, $P < 0.05$). Bars represent standard deviation from the mean.

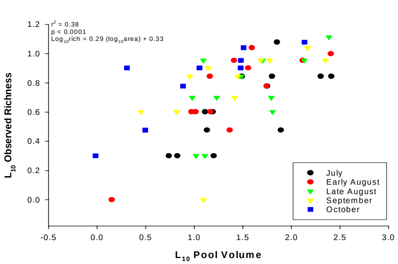


Figure 5: (Above) Observed species richness increased with pool size (ANCOVA, $F_{1,46} = 46.08$; $P<0.0001$). However, as pools dried through summer, species richness did not change, on average. Neither the slope of the relationship (ANCOVA, test of homogeneity of slopes, $F_{4,46} = 0.25$; $P = 0.91$), nor average species richness ($F_{4,46} = 1.26$; $P = 0.30$) differed across months.

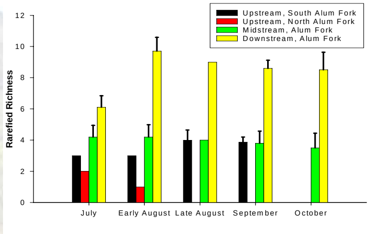


Figure 6: (Above) After standardizing for sample size, rarefied richness at a site did not significantly differ across months (repeated measures ANOVA, $F_{4,44} = 0.73$; $P = 0.57$), despite significant reductions in pool size. Illustrated sites show trends typical of all sampled sites along the stream gradient. Bars indicate standard deviation from the mean.

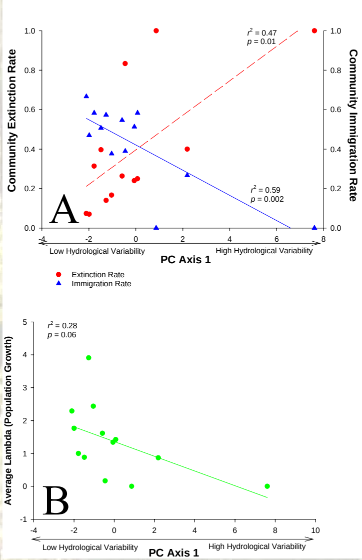


Figure 7: (Left) Population dynamics were affected by changes in pool size. Immigration rates (A) and population growth (B) decreased with increasing hydrological variability (linear regression using PC 1 as independent variable). Extinction rates (A) increased with increasing hydrological variability. Immigration rates, extinction rates, and population growth were calculated for each species at a site and averaged across months. Population growth is the proportional change in abundance from one time period to the next and included age 0 individuals. Immigration (excludes age 0 individuals) and extinction rates were calculated similar to Taylor and Warren (2001).

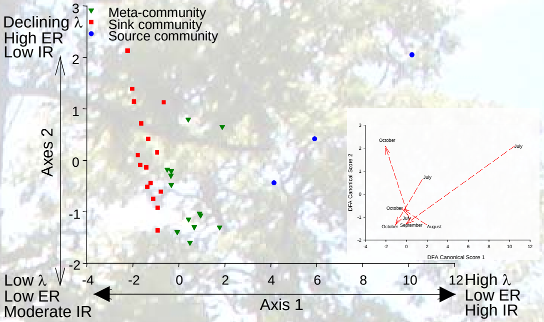


Figure 8: (Above) Canonical scores from a discriminant function's analysis that significantly separated sites based upon bi-monthly population growth rates, immigration rates, and extinction rates ($P<0.0001$). Some sites were sources of high population growth (reproduction), and some were sinks associated with high rates of population decline across species. The majority were intermediate that we consider as part of a meta-community. The *inset* shows the transition of communities from being sources or part of a meta-community early in summer to being sinks later in summer.

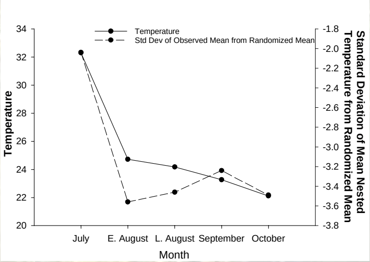


Figure 9: (Above) Throughout summer, progressively higher rates of extinction resulted in a regional pattern of increasing community nestedness. All sampling periods were characterized by significantly nested communities within the watershed ($P<0.01$, for all) indicating that small communities were nested subsets of larger communities for all months. Lower temperatures indicate higher community nestedness.

Acknowledgements

We thank the USDA forest service for funding this project. Also, we greatly appreciate the field efforts of William Hilburne, Nathan Maples, and Brook Herman.

Literature Cited

Taylor CM, ML Warren Jr. (2001) Dynamics in species composition of stream fish assemblages: environmental variability and nested subsets. Ecology 82:2320-2330

[1] Mississippi State University, Department Biological Sciences, Mississippi State, MS 39762 USA
[2] U.S.D.A. Forest Service, Southern Research Station, Forest Hydrology Lab, 1000 Front Street, Oxford, Mississippi 38655 USA
[3] Email: alopias@hotmail.com