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SPECIES-WATERSHED AREA RELATIONSHIPS FOR FISHES IN THE KANSAS-REPUBLICAN RIVER BASIN, USA

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The general biogeographical relationship of the number of species increasing with area was studied in reference to fish and watershed areas for the Kansas and Republican river systems in Kansas, Nebraska, and Colorado. For the entire Kansas River and Republican River basins, there were weakly positive but not statistically significant relationships between watershed area and the number of native species (r = 0.14, p = 0.333) *or native families* (r = 0.18, p = 0.190). *For the entire Republican River basin (with one Kansas River site), correlations were slightly stronger but still not significant for native species* (r = 0.26, p = 0.281) *or native families* (r = 0.40, p = 0.088). *For nested watersheds of the Republican and Kansas rivers, however, the correlations were stronger* (*for native species* r = 0.92, p = 0.013; *for native families,* r = 0.56, p = 0.192). *A strong east to west increase in the harshness of environmental conditions in Great Plains streams, however, likely contributes substantially to this relationship. Environmental conditions result in fewer species in western catchments. A set of watersheds in the Republican River Basin, increasing in size from east to west, showed no significant correlation between watershed area and the number of native species or native families.*

INTRODUCTION

Most often applied to terrestrial systems, the species-area relationship is considered one of community ecology's few laws. Generally stated, species number tends to increase with increasing area, regardless of taxonomic group or ecosystem type (Brown and Lomolino 1998, Rosenzweig 1995). This relationship has been one of the earliest and most thoroughly documented ecological patterns. In a study of ecoregions and drainage area to explain species groupings, Newall and Magnusen (1999) found that fish community composition in Wisconsin was not independent of drainage area. Oberdorff et al. (1995) studied fish species in major rivers on all continents and found that two strongest correlates of species richness were total surface area of the drainage basin and mean annual discharge. Watters (1992) concluded that the number of fish species in Ohio River drainages may be predicted by the area of the drainage basin. Matthews and Robison (1998) found that species-area slopes in Arkansas were significantly different from zero, except for minnows.

However, not all studies have shown a fish species richness–watershed area relationship. Rohde (1997) stated that area per se was not correlated with species number of freshwater fishes of Eurasia; warm tropical regions have significantly greater species numbers than the much larger cold-temperate regions of the continent. Angermeier and Schlosser (1989) found habitat volume a better predictor of species richness than habitat area. Livingstone et al. (1982) found that the number of freshwater fish species in African rivers was more closely related to discharge than to river length or catchment area. The objective of this exercise was to explore whether species-area relationships could be derived from a database of fishes collected at randomly selected stream sites in the U.S. Central Plains.

METHODS

Field crews from the U.S. EPA Region VII sampled the fish community throughout the study area (Nebraska, Kansas, and Missouri) during the late spring and summer of 1994 and 1995 as part of its Regional Environmental Monitoring and Assessment Program (REMAP) (EPA, 1993). In their study, two hundred ninety sites, primarily streams to small rivers, were randomly selected in Kansas and Nebraska to assess fisheries health and stream condition, and to establish baseline data and methods usable for assessing long-term trends throughout the region (EPA, 1994). Stream sections from a digital hydrography file were divided into segments and randomly selected by the EPA. The Missouri, Mississippi and Arkansas rivers were not sampled, and only a few samples were taken from the Kansas and Platte rivers. Streams were sampled once in 1994 or 1995, when stream flows were close to seasonal norms. Field sampling was generally conducted between June and September when flows are generally low, pollution stress is potentially high and the fish community is the most stable and sedentary (EPA, 1994). Standard protocol involving seining and/or electroshocking techniques were used to sample the fish community (EPA, 1994).

For this study, ninety-one sample sites in the Kansas River Basin were used. Three variables examined were log number of native species, log number of native families and log watershed area. Four scenarios were tested: 1) all sampled watersheds in the Kansas River Basin; 2) all sampled watersheds in the Republican River Basin (with one Kansas River sampling site); 3) nested watersheds of the Republican and Kansas rivers; and 4) watersheds chosen to show a gradient of increasing watershed size from east to west. This was done to observe whether the species-area relationship held up in such a situation. Pearson correlation analysis was used to quantify relationships between taxa number and watershed area. Figure 1 shows the watersheds used in the

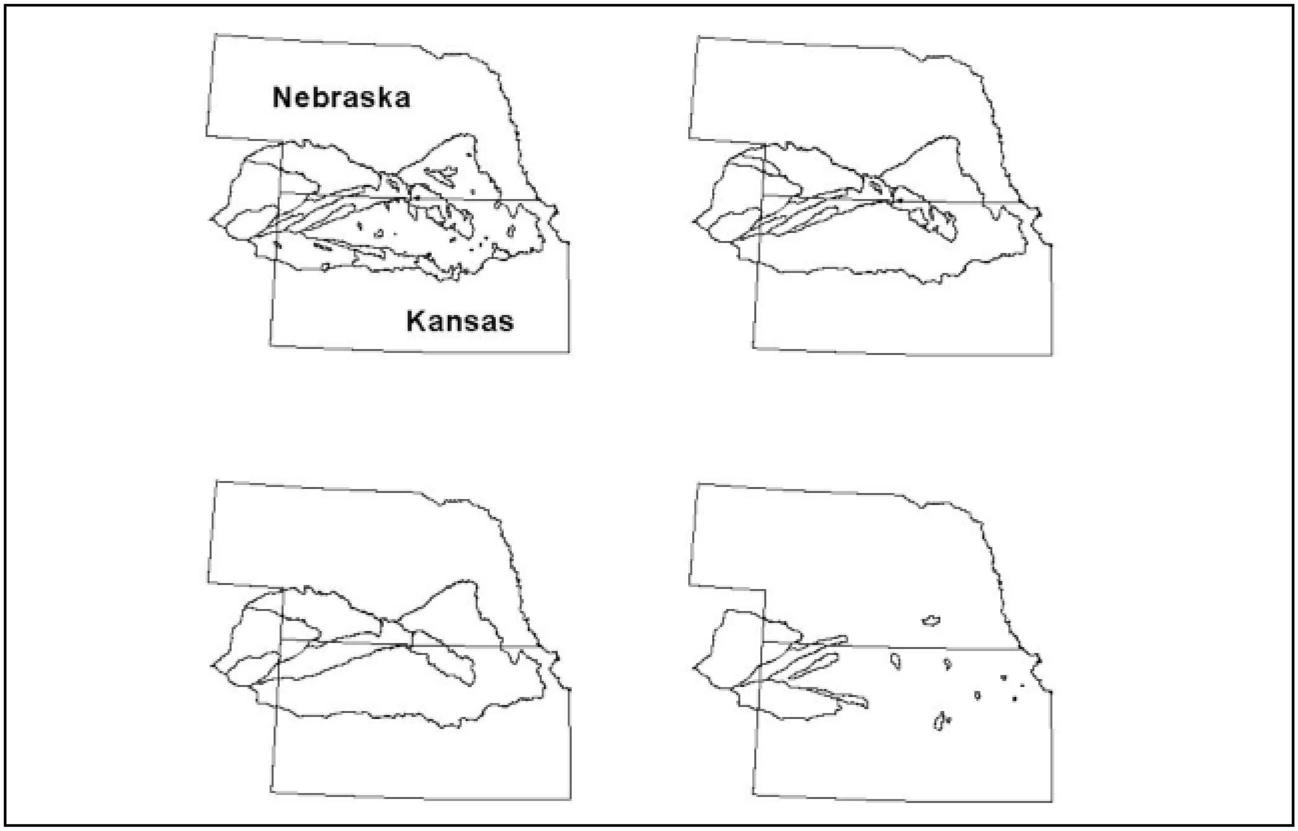

Figure 1. Sets of watersheds showing the four scenarios examined for species richness – watershed area relationships. Top left) Scenario 1 – all sampled watersheds in the Kansas River basin; Top right) Scenario 2 – all sampled watersheds in the Republican River basin (plus one Kansas River site); Bottom left) Scenario 3 – nested watersheds of the Republican-Kansas River system; Bottom right) Scenario 4 – the set of watersheds increasing in area from east to west.

four scenarios. Watershed area was calculated as the drainage area above the sampling point. In scenario three, the Kansas River was considered a watershed within the Republican River.

RESULTS

Scatterplots of and correlation coefficients between taxa number and watershed area are shown in Figures 2 and 3. For watersheds in the entire Kansas River Basin, there were weakly positive correlations between the number of native species and families and watershed area. In the Republican River Basin, correlations were slightly stronger but still not significant for native species and native families. For truly nested watersheds on the Republican and Kansas Rivers, however, there was a strong relationship ($r = 0.92$, $p = 0.013$) between watershed area and the number of native species, and a positive relationship between area and the number of native families ($r = 0.56$) albeit not statistically significant at $\alpha = 0.05$. For the set of watersheds that increased in area from east to west, there was actually a negative relationship (albeit not statistically significant) between watershed area and native species ($r = -0.38$, $p = 0.112$) and native families numbers ($r = -0.14$, $p = 0.563$).

DISCUSSION

The lack of strong correlations between area and taxa number when using all of the watersheds in the Kansas River Basin is not surprising. Included within this set were many small and medium-

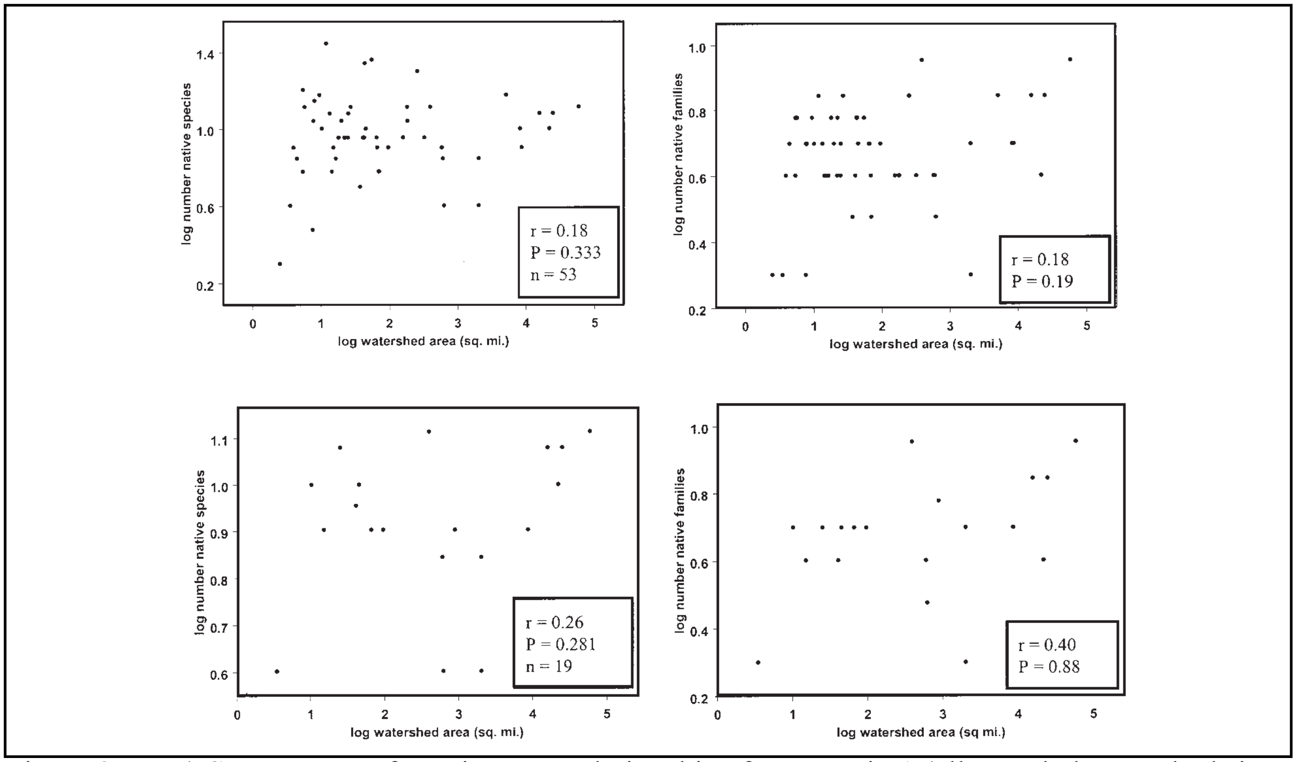

Figure 2. Top) Scattergram of species-area relationships for scenario 1 (all sampled watersheds in the Kansas River basin), for native species and native families; Bottom) Scattergram of species-area relationships for scenario 2 (all sampled watersheds in the Republican River basin [plus one Kansas River site]), for native species and native families.

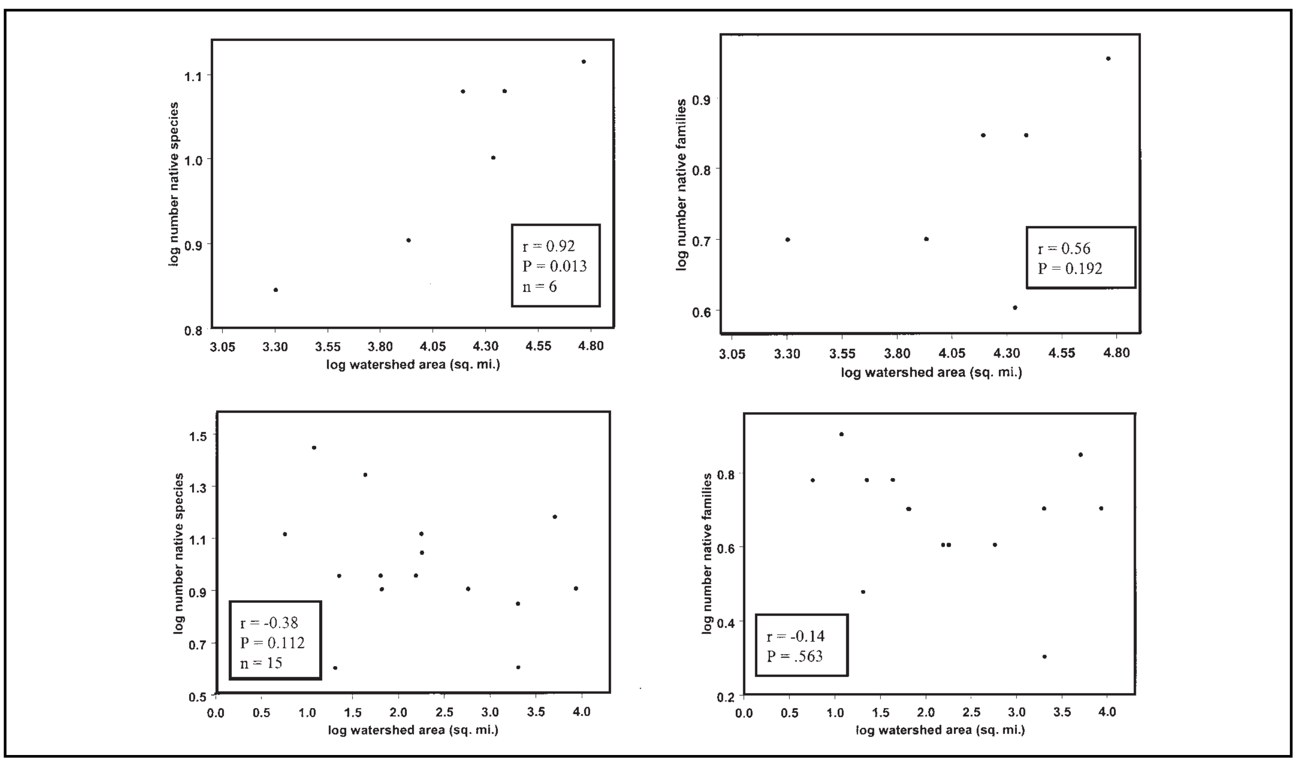

Figure 3. Top) Scattergram of species-area relationships for scenario 3 (nested watersheds of the Republican-Kansas River system), for native species and native families; Bottom) Scattergram of species-area relationships for scenario 4 (the set of watersheds increasing in area from east to west) , for native species and native families.

sized watersheds, and only a few large watersheds. Because stream sampling sites were randomly selected, other factors that affect fish community composition were not controlled for, such as geology, slope, soils, geomorphology, and point sources of pollution or other human disturbance. Furthermore, a range of land cover in these watersheds existed, from mostly rangeland to mostly agricultural. Therefore, for watersheds of roughly the same size, a number of factors other than area can cause variation in the number of species. These factors affect water quality, which in turn impacts the fish community. This appeared to be the case for watersheds between 10 and 400 sq. mi. The lack of truly nested watersheds in this set may also have played a role in the outcome. The Kansas River watershed spans different ecoregions, and differing environmental conditions in different subcatchments may be affecting species composition (Taylor et al., 1993). In addition, the samples were collected from June through September. Taylor et al. (1996) found temporal variation between June and September in fish assemblages in a Great Plains stream. Temporal variability in several environmental parameters was significantly associated with fish assemblage variability through time. The same can be said for all watersheds in the Republican River Basin, although the variation is not quite as high so the correlations are slightly stronger.

Nested watersheds in the Republican River Basin showed a very strong relationship between watershed area and taxa number. How much of this relationship truly derives from watershed area, however, cannot be positively determined from these data. As one travels eastward in the U.S. Central Plains, harshness of environmental conditions greatly decreases (Cross et al., 1986, Cross and Moss 1987). A set of watersheds that increases in size from east to west was investigated to observe whether the species-area relationship held up under this condition. Because there are no major streams that flow from east to west, nor north-south, this set of watersheds necessarily could not be truly nested. As shown in Figure 3, there was in fact a negative relationship, although not statistically significant. This result is likely due to environmental conditions that override any species-area relationship. Livingstone (1982) stated that “discharge is directly proportional to terrestrial productivity of a river basin, which in turn, affects total biomass of fish and the number of species.” This applies well to the east-west gradient situation in Great Plains streams. Marsh-Matthews and Matthews (2000) also found that species richness in midwestern streams was explained by longitude as well as in-stream factors. Angermeier and Schlosser (1989) found weak relationships between species richness and habitat volume or complexity. This may be especially true when the random nature of the samples here is taken into account.

CONCLUSION

From a fish taxa number database at stream locations within the Kansas River system of the Great Plains, a strong species-area relationship was found only for a subsample of truly nested watersheds. Only weak relationships, or those not statistically significant, were observed when all watersheds in the Kansas River Basin or Republican River Basin were used. I suggest this emanates from other environmental factors which influence water quality and fish distribution in this area. Environmental conditions likely influenced the strong relationship found, because for watersheds that increased in size from east to west, there was a negative relationship between watershed area and native species and family numbers. Traveling east to west, one actually might be staying at the same volume of discharge, even though watershed area is increasing. Additionally, the sites have not been controlled for nearby disturbances. Finally, the very high relationships for nested species likely results from the eastward decrease in the harshness of the environment and greater stream discharge.

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