

## Homogenization of fish faunas in two categories of streams in a single basin in Kansas and the choice of similarity coefficients

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The process of biotic homogenization represents an increased similarity among communities in their taxonomic, genetic, or functional attributes (Olden et al. 2004) through the loss of unique elements of native communities and the addition of widespread, nonnative elements (McKinney and Lockwood 1999). Thus, homogenization can result from introductions, extirpations, or both (Olden and Poff 2003; Olden and Poff 2004). Most assessments of the homogenization of fish faunas in streams have focused on comparisons of communities among basins, ecoregions, or states (Duncan and Lockwood 2001; Marchetti et al. 2001; Carlson and Daniels 2004). However, Scott and Helfman (2001) compared fish faunas in highland and lowland streams in the southeastern USA and discussed the importance of assessments at these smaller scales. Streams in western Kansas and their communities have undergone substantial changes since the state was established in 1861 (Cross and Moss 1987; Bergman et al. 2000). We used information summarized in a study on changes in the fish faunas of the Solomon River basin in north-central Kansas (Eberle et al. 2002) to assess the degree of homogenization that might have occurred between faunas characteristic of two general types of streams in a single basin in western Kansas.

Eberle et al. (2002) categorized fish species in the Solomon River basin as characteristic of low-discharge streams (e.g., small, perennial creeks and river headwaters), characteristic of high-discharge streams (e.g., braided, sandy rivers and deeper channels), or common

to both types of streams. They based these categorizations on analysis of the presence of the species in samples collected in streams within the basin. Using data from Eberle et al. (2002), we assigned presence or absence of each species to each type of stream (Table 1). To compare similarity between the faunas characteristic of low-discharge and high-discharge streams, we calculated two similarity coefficients: Jaccard's coefficient (Jaccard 1908), which is commonly used to assess similarity in the context of homogenization of fish communities (Rahel 2002), and Unnamed Coefficient Number 4 (UN4; Sokal and Sneath 1963, sensu Rohlf 1994). The formulas for the two coefficients are:

$$\text{Jaccard's} = a / (a + b + c)$$

$$\text{UN4} = 0.25 \times ((a / (a + b)) + (a / (a + c)) + (d / (b + d)) + (d / (c + d)))$$

where "a" = the number of species present in both communities, "b" = the number of species present in the first community but not the second, "c" = the number of species present in the second community but not the first, and "d" = the number of species absent from both communities. Calculated values for both coefficients range from 0 to 1.

Initially, we made two comparisons of the similarity of the faunas of the low-discharge and high-discharge streams. In the first comparison (historical faunas), the list of species (Table 1) included only the 25 species that were probably native to the basin in the mid 1800s prior to EuroAmerican settlement.

Species	Historical		Extant		Extant and Extirpated	
	LDS	HDS	LDS	HDS	LDS	HDS
Longnose Gar, <i>Lepisosteus osseus</i>	0	1	0	1	0	1
Shortnose Gar, <i>Lepisosteus platostomus</i>			0	1	0	1
Goldeye, <i>Hiodon alosoides</i>	0	1			0	0
Gizzard Shad, <i>Dorosoma cepedianum</i>			0	1	0	1
Central Stoneroller, <i>Campostoma anomalum</i>	1	0	1	0	1	0
Red Shiner, <i>Cyprinella lutrensis</i>	1	1	1	1	1	1
Common Carp, <i>Cyprinus carpio</i>			1	1	1	1
Plains Minnow, <i>Hybognathus placitus</i>	0	1			0	0
Common Shiner, <i>Luxilus cornutus</i>	1	0			0	0
Redfin Shiner, <i>Lythrurus umbratilis</i>	1	0			0	0
Golden Shiner, <i>Notemigonus crysoleucas</i>			0	1	0	1
Emerald Shiner, <i>Notropis atherinoides</i>			0	1	0	1
Sand Shiner, <i>Notropis stramineus</i>	1	1	1	1	1	1
Topeka Shiner, <i>Notropis topeka</i>	1	0			0	0
Suckermouth Minnow, <i>Phenacobius mirabilis</i>	1	1	1	1	1	1
Southern Redbelly Dace, <i>Phoxinus erythrogaster</i>	1	0			0	0
Bluntnose Minnow, <i>Pimephales notatus</i>	1	0	1	0	1	0
Fathead Minnow, <i>Pimephales promelas</i>	1	0	1	0	1	0
Bullhead Minnow, <i>Pimephales vigilax</i>			0	1	0	1
Creek Chub, <i>Semotilus atromaculatus</i>	1	0	1	0	1	0
River Carpsucker, <i>Carpiodes carpio</i>	0	1	0	1	0	1
White Sucker, <i>Catostomus commersoni</i>	1	0	1	0	1	0
Smallmouth Buffalo, <i>Ictiobus bubalus</i>			0	1	0	1
Bigmouth Buffalo, <i>Ictiobus cyprinellus</i>			0	1	0	1

Table 1. Fish species in the Solomon River basin, Kansas, designated as present or absent in low-discharge streams (LDS) and high-discharge streams (HDS). "1" = present; "0" = absent; no value = species not included in this data set. "Historical" = fish species present in mid 1800s; "Extant" = fish species collected during 1996-1997 surveys; "Extant and Extirpated" = status in 1996-1997 of all fish species reported from the study area. Data derived from summary by Eberle et al. (2002).

Species	Historical		Extant		Extant and Extirpated	
	LDS	HDS	LDS	HDS	LDS	HDS
Shorthead Redhorse, <i>Moxostoma macrolepidotum</i>	0	1			0	0
Black Bullhead, <i>Ameiurus melas</i>	1	1	1	1	1	1
Yellow Bullhead, <i>Ameiurus natalis</i>			1	0	1	0
Channel Catfish, <i>Ictalurus punctatus</i>	0	1	0	1	0	1
Stonecat, <i>Noturus flavus</i>	1	1	1	1	1	1
Flathead Catfish, <i>Pylodictis olivaris</i>			0	1	0	1
Northern Plains Killifish, <i>Fundulus kansae</i>	1	1	1	1	1	1
Western Mosquitofish, <i>Gambusia affinis</i>			0	1	0	1
White Bass, <i>Morone chrysops</i>			0	1	0	1
Green Sunfish, <i>Lepomis cyanellus</i>	1	1	1	1	1	1
Orangespotted Sunfish, <i>Lepomis humilis</i>	1	1	1	1	1	1
Bluegill, <i>Lepomis macrochirus</i>			1	1	1	1
Largemouth Bass, <i>Micropterus salmoides</i>			1	1	1	1
White Crappie, <i>Pomoxis annularis</i>			0	1	0	1
Black Crappie, <i>Pomoxis nigromaculatus</i>			0	1	0	1
Johnny Darter, <i>Etheostoma nigrum</i>	1	0			0	0
Orangethroat Darter, <i>Etheostoma spectabile</i>	1	0	1	0	1	0
Logperch, <i>Percina caprodes</i>			1	1	1	1
Freshwater Drum, <i>Aplodinotus grunniens</i>			0	1	0	1

Table 1. Fish species in the Solomon River basin, Kansas, cont'd.

In the second comparison (extant faunas), the list of species (Table 1) included the 35 native and nonnative species extant in the basin in surveys conducted during 1996-1997 (Eberle et al. 2002). To assess whether the similarity coefficients for each period differed significantly from random, we ran a Monte Carlo simulation (50,000 iterations) of similarity coefficients generated randomly with Resampling Stats Add-in for Microsoft Excel (Resampling Stats, Inc., Arlington, Virginia). For each period, we held the presence or absence of species in the low-discharge streams constant and allowed the presence or absence of species in the high-

discharge streams to be randomly assigned; we held the number of species present in the high-discharge streams constant with the actual species richness. This provided us with 50,000 randomly generated values for both similarity coefficients. We then compared the two actual similarity coefficients for each period to the respective randomly generated values to assess significance. Subsequently, for both similarity coefficients, we randomly paired the 50,000 randomly generated values from the two time periods (i.e., historical and extant faunas) and calculated differences between these pairs of values to assess the degree of change in similarity. We then

compared these difference values to the actual difference between the similarity coefficients for the two periods to assess significance. In both analyses, we assessed significance at  $P < 0.05$ .

Analysis of the similarity coefficients for the historical faunas (Jaccard's = 0.320; UN4 = 0.248) indicated that the faunas in the low-discharge and high-discharge streams were significantly dissimilar ( $P = 0.017$ ), which reflected the fact that only 32% (8 of 25) of the species were common to both types of streams. Of the remaining species, 44% (11 of 25) were classified as characteristic of low-discharge streams and 24% (6 of 25) were classified as characteristic of high-discharge streams.

As with the historical faunas, analysis of the similarity coefficients for the extant faunas (Jaccard's = 0.343; UN4 = 0.265) indicated that the faunas in the low-discharge and high-discharge streams were significantly dissimilar ( $P = 0.007$ ), which reflected the fact that only 34% (12 of 35) of the species were common to both types of streams. Of the remaining species, 20% (7 of 35) were classified as characteristic of low-discharge streams and 46% (16 of 35) were classified as characteristic of high-discharge streams.

Although the similarity coefficients were virtually unchanged for the historical faunas and the extant faunas, the relative proportions of species characteristic of each type of stream were reversed: more species in the historical faunas were classified as characteristic of low-discharge streams, but more species in the extant faunas were characteristic of high-discharge streams. This resulted from relatively more extirpations of species characteristic of low-discharge streams and relatively more additions of nonnative species characteristic of high-discharge streams. Thus, additions and extirpations contributed to substantial changes in the fish faunas of the two types of streams, even though the

similarity coefficients remained virtually the same in the two periods.

However, the initial calculation of similarity coefficients for the extant faunas did not fully reflect the role of the extirpations in the changes observed – the eight extirpated species were not included in the list of 35 extant species used to calculate the similarity coefficients. Thus, we calculated the similarity coefficients a third time based on a list of all 43 extant and extirpated species (Table 1). In this calculation, the Jaccard's coefficient (0.343) was unchanged from the value calculated with the list of species that omitted the eight extirpated species. However, the UN4 similarity coefficient increased from 0.265 to 0.482, because the absence of species from both types of streams (equation element “d”) is integral to the calculation, unlike the calculation for Jaccard's coefficient.

The distance between the similarity coefficients for the historical faunas (Jaccard's = 0.320; UN4 = 0.248) and the faunas that included only the 35 extant species (Jaccard's = 0.343; UN4 = 0.265) was not significantly different than expected by chance ( $P = 0.114$ ), suggesting no trend toward homogenization of the faunas. However, the distance between the UN4 similarity coefficients for the historical faunas (UN4 = 0.248) and the faunas that included all 43 extant and extirpated species (UN4 = 0.482) was significantly different ( $P = 0.049$ ), reflecting the changes associated with the extirpations of species within the study area and suggesting a trend toward homogenization. Thus, the choices of similarity coefficient and species pool (i.e., either including or excluding extirpated species) are important to any inferences drawn from this study.

Similarity coefficients can be grouped into two categories based on their inclusion or exclusion of equation element “d” (e.g., a species is absent from both communities) in the calculation (Legendre and Legendre

1998). Symmetrical coefficients (e.g., UN4) include both equation elements of similarity: “d” and “a” (a species is present in both communities). Asymmetrical coefficients (e.g., Jaccard’s) include equation element “a” but not equation element “d”. In our study, the use of Jaccard’s coefficient as the asymmetrical coefficient of similarity was based on its use in other studies on homogenization of fishes (Radomski and Goeman 1995; Rahel 2000; Marchetti et al. 2001). We are aware of no other studies on homogenization of fish faunas that have used UN4 or another symmetrical coefficient of similarity. We used UN4 rather than one of the other symmetrical coefficients because it compares similarities (equation elements “a” and “d”) to differences (equation elements “b” and “c”) on a scale of 0-1 (the same scale as Jaccard’s) without emphasizing either the similarities or the differences between the objects (Legendre and Legendre 1998).

The decision to use either a symmetrical or an asymmetrical coefficient depends on whether equation element “d” is a valid component of similarity between two objects (Legendre and Legendre 1998). For example, if we compare fish species from two creeks collected during the same sample period, absence of species from both samples would not be a valid component of their perceived similarity. In such a comparison, we would have no valid basis for assuming that the absent species should be present in one or both creeks at the time we collected our samples. Thus, an asymmetrical coefficient would be appropriate. However, if we introduce a temporal dimension and compare the similarity of the faunas across time, then the absence of species that were formerly present becomes relevant to the assessment of similarity, because extirpations alone can alter the degree of similarity, as outlined by Olden and Poff (2003, 2004) in several scenarios that can cause homogenization of communities. In this instance, a symmetrical coefficient would be appropriate.

Unlike Jaccard’s coefficient, our second analysis of UN4 similarity coefficients for the historical and extant faunas (including the eight extirpated species) indicated that there was a significant increase in similarity (a trend toward homogenization) between the fish communities inhabiting the low-discharge and high-discharge streams. This is because the UN4 coefficient fully reflected the concept that communities can become more similar not only through the addition of species that are then present in both communities, but also through the loss of species that formerly made them more dissimilar. In other words, the two communities in the Solomon River basin became more similar because the symmetrical UN4 similarity coefficient gave equal weight to the presence of species in both communities and to the absence of species in the study area in 1996-1997 that were formerly characteristic of one stream type or the other.

We consider this increase in calculated similarity to be a valid conclusion based on the premise that extirpated species should be retained as part of the community, at least conceptually, because an essential goal of conservation is restoring extirpated native species in at least a portion of their former range, in addition to reducing the presence of nonnative species. Success in the conservation of native communities typically is judged by how little change has occurred in the communities following exposure to anthropogenic impacts that can alter their composition and processes. Thus, the extirpation of native species is an important process that should be fully incorporated into any metrics used to assess the conservation of native communities.

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