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Keywords

fish assemblages, habitat, Iowa, common carp, biotic integrity, environmental degradation

Disciplines

Aquaculture and Fisheries | Natural Resources Management and Policy | Veterinary Microbiology and Immunobiology

Comments

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Fish Assemblages of the Upper Little Sioux River Basin, Iowa, USA: Relationships with Stream Size and Comparison with Historical Assemblages

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ABSTRACT

We characterized the fish assemblages in second to fifth order streams of the upper Little Sioux River basin in northwest Iowa, USA and compared our results with historical surveys. The fish assemblage consisted of over twenty species, was dominated numerically by creek chub, sand shiner, central stoneroller and other cyprinids, and was dominated in biomass by common carp. Most of the species and the great majority of all individuals present were at least moderately tolerant to environmental degradation, and biotic integrity at most sites was characterized as fair. Biotic integrity declined with increasing stream size, and degraded habitat in larger streams is a possible cause. No significant changes in species richness or the relative distribution of species' tolerance appear to have occurred since the 1930s.

INTRODUCTION

Streams in agricultural regions reflect the influence of altered land use in their drainage basins, as forests and grasslands are turned into planted fields and pastures (Karr et al. 1985, Waters 1995). Nowhere are these influences more prevalent than in Iowa (Heitke et al. in press). Nearly 90% of Iowa land has been converted to agricultural use (Natural Resources Conservation Service 2000). Land clearing, wetland drainage and channelization played prominent roles in conversion of Iowa from a predominantly tall–grass prairie landscape to an agricultural landscape. In addition to profoundly changing the nature of existing streams (Menzel et al. 1984), channelization reduced the total length of Iowa streams by over 4800 km (Bulkley 1975) while wetland drainage resulted in creation of many artificial streams through areas that were previously intermittant wetlands (Anderson 2000).

Because fish assemblages are known to respond to many of the changes associated with agriculture and other types of human alteration, there is considerable interest in using fish assemblages as indicators of the biotic integrity of aquatic systems (Karr et al. 1985, Simon 1999). Because biotic integrity measures responses of living organisms that adapt to conditions around them, biotic integrity reflects chemical, physical and biological impacts as well as cumulative environmental impacts (Simon 1999). Fish are considered ideal among aquatic organisms for assessment of biotic integrity because they are at the apex of the aquatic food web, their life cycles are long relative to fluctuations in environmental conditions, and non-professionals as well as professional biologists and managers are familiar with and interested in the well-being of fish (Karr et al. 1986).

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Long-term records of fish assemblage composition and change are rare but are potentially valuable in documenting changes associated with human alteration over time. For example, in Spirit Lake, Iowa, comparison of collections from the 1990s with historical records from the 1920s revealed a 25% decline in the number of native species (Pierce et al. 2001). The century-long record of changes in the stream fish assemblages of Champaign County, Illinois (Larimore and Bayley 1996) is another example of the potential value of long-term records of fish assemblage composition.

The purpose of this study was to characterize the fish assemblages in streams of the upper Little Sioux River basin and to compare the contemporary status with historical records.

METHODS AND MATERIALS

The upper Little Sioux River basin (ULSRB), located in northwest Iowa, occupies two subregions of the Western Corn Belt ecoregion - the Des Moines Lobe (DML) and the Northwest Iowa Loess Prairies (NIP, Griffith et al. 1994). Historically, the land cover was primarily tall-grass prairie with forested stream valleys (Prior 1991), but today ninety-six percent of the land in this area is devoted to agriculture (Iowa Agricultural Statistics Service 1995). In this basin, we sampled 11 wadeable sites on streams ranging from second to fifth order, with drainage areas ranging from 19 to 1,418 km^2 (Table 1). Sites were chosen to encompass the size range of permanent yet wadeable streams in the ULSRB and to correspond to sites used in previous surveys (Loan-Wilsey et al. 2005) where possible. Species-accumulation curves for stream electrofishing in Smith and Jones (2005) suggest that 11 sites would likely reveal a high percentage (>70%) of the species present in the ULSRB.

Table 1. Location, channel, and basin information for eleven sites in the upper Little Sioux River basin, Iowa. DML = Des Moines Lobe; NIP = Northwest Iowa Loess Prairies.

Site			Coordinates		Drainage	Stream
Number	Stream	Ecoregion	UTM - X	UTM – Y	Area (Km^2)	Order
1	Little Sioux River	DML	317800	480830	782	5
2	Little Sioux River	DML	323000	477850	1418	5
3	Dugout Creek	DML	311800	480820	19	2
4	Big Muddy Creek	DML	333800	478850	130	2
5	Ocheyedan River	NIP	296300	480160	337	3
6	Ocheyedan River	DML	318800	477750	1104	5
7	Little Ocheyedan River	NIP	292700	478100	91	3
8	Stony Creek	DML	318800	477750	221	4
9	Willow Creek	NIP	320900	476120	183	3
10	Waterman Creek	NIP	302200	476400	296	4
11	Mill Creek	NIP	284600	475300	455	4

We sampled each site using a combination of electrofishing and seining. Although electrofishing was our primary sampling method, we used seining to assess the possibility of certain species being missed by electrofishing, and in the few cases where species were collected at a site by the seine but not by electrofishing we included those additional species as part of the observed species richness for that site.

Our primary electrofishing gear was an electric seine (Bayley et al. 1989). The electric (AC) seine consisted of a 10 m floating cable, with 11 drop-electrodes 38 cm in length and spaced at 76 cm intervals along the cable, and a hand-held probe electrode at each end of the floating cable. The upstream end of each site was blocked with a 5 mm mesh net before starting the sampling. We worked upstream from the downstream end of a site toward the block net in a single pass. Our secondary electrofishing gear was a pulsed-DC backpack electrofisher (Smith-Root 15-C POW) and wa sused at three sites (sites 7, 10 and 11) where the channel was either too narrow or shallow to use the electric seine. After electrofishing at each site, we performed two sweeps with a 5 mm mesh seine in an upstream direction just outside of the area electrofished.

Fish sampling was conducted during the daytime (0900 to 1700 h) between 25 June and 15 July, 2002. Lengths of stream electrofished ranged from 32 m to 195 m, depending on stream size. We attempted to identify all fish on site, measure their total length and wet weight, and release them alive. Specimens too abundant to be processed at the stream or requiring microscopic examination for identification were anesthetized in 1-2% MS- 222 and preserved in 10% formaldehyde. Preserved fish were later identified, measured, and weighed in the laboratory.

We obtained data reflecting drainage basin and stream channel characteristics at each site from the Iowa Rivers Information System (IRIS) (Brown et al. 2002) for comparison with fish assemblages. GPS was used to record the UTM coordinates of sampling sites in the field. IRIS was used to retrieve stream order and drainage area for each sampling site (Table 1).

To assess long-term trends in fish assemblages in the ULSRB we compared our 2002 survey with historical data obtained from a comprehensive database of all riverine

Table 2. Density catch-per-unit-effort ($CPUE_D$) and biomass catch-per-unit-effort ($CPUE_B$) for fish species collected by electrofishing at eleven sites in the upper Little Sioux River basin, Iowa.

Species	Sites Present	$CPUE_D$ (# fish/100 m) Mean	% of total	$CPUE_B$ (g/100 m) Mean	% of total
Creek chub (*Semotilus atromaculatus*)	3-11	45	21	959	14
Sand shiner (*Notropis stramineus*)	1, 2, 4-11	36	17	83	1
Central stoneroller (*Campostoma anomalum*)	2, 4, 5, 7-11	33	15	316	5
Bigmouth shiner (*Notropis dorsalis*)	4-11	23	11	69	1
Common shiner (*Luxilus cornutus*)	4, 5, 7-11	22	10	286	4
Unidentified cyprinids	1, 3-6, 9, 10	17	8	16	<0.5
Bluntnose minnow (*Pimephales notatus*)	3-11	11	5	45	1
White sucker (*Catostomus commersoni*)	2-11	10	4	1,102	16
Green sunfish (*Lepomis cyanellus*)	1-10	9	4	35	1
Red shiner (*Cyprinella lutrensis*)	1, 2, 4-11	5	2	14	<0.5
Common carp (*Cyprinus carpio*)	1-4, 6, 8, 11	3	2	2,728	41
Johnny darter (*Etheostoma nigrum*)	1-5, 7, 9-11	3	1	9	<0.5
Quillback (*Carpiodes cyprinus*)	1, 2, 6, 11	2	1	86	1
Stonecat (*Noturus flavus*)	1, 4, 5, 7, 9, 10	2	1	88	1
Black bullhead (*Ameiurus melas*)	1, 3-5, 7-9	1	1	29	<0.5
Shorthead redhorse (*Moxostoma macrolepidotum*)	1, 2, 4, 6, 9-11	1	1	717	11
Northern pike (*Esox lucius*)	1, 3, 4, 6, 8, 9	<0.5	<0.5	173	3
Iowa darter (*Etheostoma exile*)	3, 5	<0.5	<0.5	<0.5	<0.5
Fathead minnow (*Pimephales promelas*)	5, 7	<0.5	<0.5	1	<0.5
Channel catfish (*Ictalurus punctatus*)	1	<0.5	<0.5	37	1
Yellow perch (*Perca favescens*)	7	<0.5	<0.5	4	<0.5
Southern redbelly dace (*Phoxinus erythrogaster*)	11	<0.5	<0.5	<0.5	<0.5
Bluegill[a] (*Lepomis macrochirus*)	6	0	0	0	0

[a] No bluegill were collected by electrofishing.

fish assemblage samples in Iowa compiled from published and unpublished reports dating back to the late 1800s (Loan-Wilsey et al. 2005). The data was extracted from the database through a query limited by stream name and location to samples taken only in the ULSRB, and a subset of 132 fish assemblage samples at 80 sites from 21 surveys, the earliest of which was recorded in 1932, was analyzed. Most of the historical records did not include data on abundances or sampling effort, so the historical data we obtained for comparison was species-presence only.

Data analysis

We used a variety of analytical techniques to characterize fish assemblages in the ULSRB. Density catch-per-unit-effort ($CPUE_D$; number of fish per 100 m of stream length) and biomass catch-per-unit-effort ($CPUE_B$; wet weight of fish per 100 m of stream length) were calculated for individual species and for the entire assemblage at each site. Tolerance to environmental degradation was examined by quantifying the percentages of species classified as tolerant, intermediate, or sensitive. An index of biotic integrity (IBI) score for each site was calculated using the computer program described in Wilton (2004). We used Wilton's (2004) version of the IBI for Iowa streams where IBI scores can range from 0 to 100, with scores 71 to 100 rated as excellent, 51 to 70 good, 26 to 50 fair, and 0 to 25 poor. We used correlation, regression, analysis of variance (ANOVA), and graphical analysis to evaluate relationships of fish assemblages with ecoregion, stream order, and drainage area.

Since comparisons of species richness among different studies are potentially biased by unknown differences in sampling efficiency, for comparisons of our 2002 survey with historical surveys we calculated estimates of true species richness in addition to observed species richness for each survey. Following the recommendations of Walsh et al. (2002), we estimated true species richness with the Chao 2 estimator according to Colwell and Coddington (1994).

RESULTS

Fish assemblages

We collected and identified a total of 4,784 fish from 22 different species (Table 2). Additional species collected by seining were rare, and had negligible influence on overall CPUE. Therefore, we used only the electrofishing data for quantifying CPUE and IBI. Applying the Chao 2 estimator to our observed survey data resulted in estimated true species richness for the ULSRB of 26. The average number of species collected per site was 13, ranging from 10 to 16. Only one introduced species, common carp (*Cyprinis carpio*), was found.

In the entire USLRB, total $CPUE_D$ averaged 301 fish/100 m, ranging from 29 fish/100 m to 831 fish/100 m per sampling site. Creek chub (*Semotilus atromaculatus*) was the most abundant species among the 11 sites, with an average $CPUE_D$ of 45 fish/100 m (Table 2). The three most numerically abundant species overall, creek chub, sand shiner (*Notropis stramineus*) and central stoneroller (*Campostoma anomalum*) together accounted for 53% of all fish collected. Seven species accounted for less than 1% of all fish collected. Total USLRB $CPUE_B$ averaged 5.7 kg/100 m (1.5 to 10.8 kg/100 m), common carp having the highest $CPUE_B$, averaging 2.7 kg/100 m. The three species with the highest overall $CPUE_B$, common carp, white sucker (*Catostomus commersoni*) and creek chub, together accounted for 71% of the wet weight of all fish collected. Nine species accounted for less than 1% of the wet weight of all fish collected.

The fish assemblages in the ULSRB were composed largely of tolerant to moderately tolerant species. Species of intermediate tolerance were the most prevalent, averaging 50% of the species present at sites, followed by tolerant species at 36% and sensitive species averaging only 14% of species present at sites. When the numbers of individual fish were taken into account, sensitive fish were even more rare. Species classified as having intermediate tolerance accounted for roughly 57% of all fish collected, tolerant species accounted for roughly 42%, and sensitive species accounted for less than 1% of the fish we collected.

Biological integrity of wadeable streams in the ULSRB was characterized as fair. IBI scores at the 11 sites averaged 38, ranging from 28 to 56. Ten of the 11 sites were in the fair range (26-50), and the single site with a good rating (56) was in the lower half of the good range (51-70).

Relationships with ecoregion, basin, and stream channel characteristics

The fish assemblage characteristics we examined were similar in the two ecoregions, with one exception (Fig. 1). $CPUE_D$ values were significantly higher (ANOVA, P=0.034) in the NIP ecoregion than the DML ecoregion. However, no significant differences (P>0.1) were found between the two ecoregions for $CPUE_B$, observed number of species, percentage of sensitive species, and IBI. The mean IBI score was 38 in both ecoregions. Because of the similarity of fish assemblage characteristics in the two ecoregions, no further stratification by ecoregion was justified.

We found little evidence for relationships of $CPUE_D$, $CPUE_B$, observed number of species and percentage of sensitive species with stream size. There were no significant differences (ANOVA; P>0.05) among stream orders for these four variables. Likewise, correlations of these four variables with drainage area were not statistically significant. In contrast to these nonsignificant relationships, we found a strong negative correlation of IBI with stream size. IBI scores differed significantly (ANOVA; P<0.01) among stream orders, with a clear pattern of decline as stream order increased. There was a significant negative correlation of IBI scores with drainage area, and a linear regression explained 76% of the variation in IBI score (Fig. 2).

Historical trends

In the 70 years between the earliest ULSRB fish assemblage survey in 1932 until our 2002 survey, the historical record of 21 surveys indicates that the average number of observed species was 23, ranging from 10 to 42, and total of 67 species was recorded. The average estimated number of species was 29. Neither the observed nor the estimated number of species appeared to show any clear trend over time (Fig. 3). Likewise, proportional composition of fish assemblages with respect to tolerance to environmental degradation changed remarkably little from 1932 to 2002 (Fig. 4). The majority of species were of intermediate tolerance, followed by tolerant species; and sensitive species representing < 20% of the assemblage in every decade surveyed.

DISCUSSION

Our results for species richness and relative abundance of species were similar to results of other recent surveys in the ULSRB and surrounding ecoregions. Bernstein et al. (2000) collected 29 species in a study aimed at documenting the status of blacknose shiners (*Notropis heterolepsis*) in northwest Iowa. Surveys conducted annually from 1995-2001 in the ULSRB by the Iowa Department of Natural Resources reported an average of 22 species per survey (Wilton 2004). Surveys conducted outside the ULSRB but within the NIP and DML ecoregions during the same period recorded similar findings; surveys averaged 22 species, ranging from 15 to 31 species (Heitke et al. in press). Earlier surveys, although variable, showed roughly comparable results. Kline (1970) reported 10 species, Hansen and Muncy (1971) reported 28, Rausch and Bovbjerg (1973) reported 29, while Menzel (unpublished, cited in Loan-Wilsey et al. 2005) reported 42 species. Creek chub was the dominant species reported by Bernstein et al. (2000), and creek chub and sand shiner were the first- and second-most abundant species reported by Wilton (2004) from the ULSRB. Although there were minor differences among recent surveys in the number of species recorded and the rank order of abundance, the general picture they provide of the ULSRB fish assemblage is remarkably consistent – an assemblage of over 20 species, dominated by creek chub and other cyprinids.

Because of similarities in the species encountered and their relative abundances, our findings that species sensitive to environmental degradation made up a very small percentage of the ULSRB fish assemblage and that biotic integrity was fair were also consistent with other recent surveys in the ULSRB and surrounding ecoregions. Only about 10% of the species collected by Bernstein et al. (2000) are classified as sensitive.

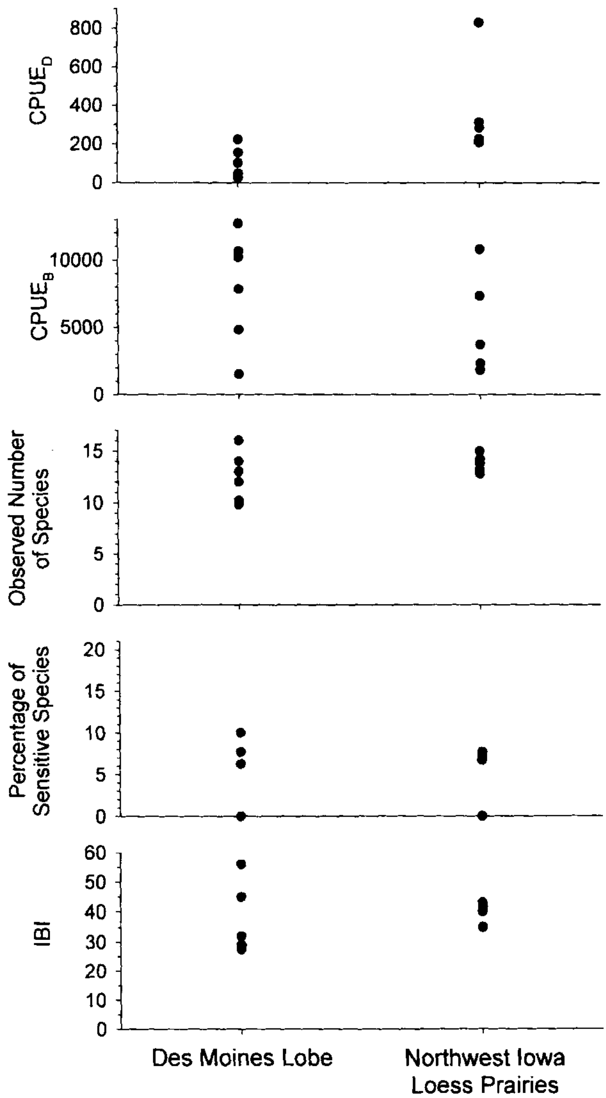

Figure 1. Fish assemblage characteristics in streams in the upper Little Sioux River basin grouped by ecoregion. Each point represents a single sampling site.

Heitke et al., (in press) reported an average of 3% sensitive species in Iowa streams tributary to the Missouri River but outside the ULSRB. Wilton (2004) reported an average IBI score of 41 in Iowa streams tributary to the Missouri River, including the ULSRB, while Heitke et al., (in press) reported an average IBI score of 47 in Iowa streams tributary to the Missouri River but outside the ULSRB. Although somewhat higher than the average IBI score of 38, the collective results characterize biotic integrity in the ULSRB as fair.

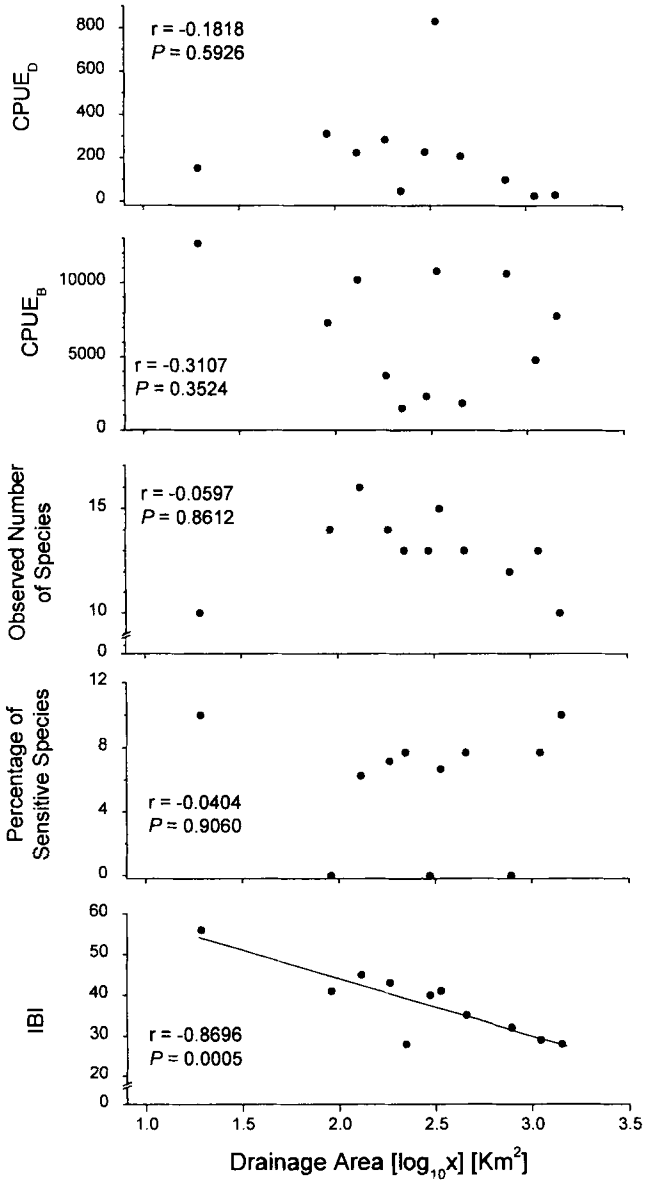

Figure 2. Fish assemblage characteristics in streams in the upper Little Sioux River basin versus drainage area. Each point represents a single sampling site. The regression line in the lower plot is: IBI= 28-56 ($\log_{10}$Drainage Area).

Variations among sites within the ULSRB in species richness, relative abundance of species, tolerance to environmental degradation, biotic integrity, and other assemblage characteristics and likely due to a variety of water quality, land use, habitat, and other influences (Wilton 2004, Heitke et al. in press). One of the potential influences we documented was a negative relationship of IBI with stream size. Many of the component IBI metrics are correlated with stream size (Karr et al. 1986, Smogor and Angermeier 1999), and these relationships are corrected for in regional IBI calibrations, which ensures that no autocorrelation between IBI and stream size exists. Indeed, Wilton (2004) reported no significant correlation between IBI and stream size in a large sample of streams across Iowa. Our relationship, implying a decline in biotic integrity from the low end of the "good" range in small streams to the bottom of the "fair" range in larger streams, has several possible explanations. Our sample size was relatively small and our sites were not selected randomly; so one explanation we cannot completely eliminate is sampling artifact. Another potential explanation is bias due to differential sampling efficiency. Streams in the ULSRB are frequently turbid. Because turbidity reduces visibility, larger streams are deeper than smaller streams, and electrofishing requires visual location of stunned fish, it is possible that sampling efficiency was lower at our larger sites than at our smaller sites due to reduced visibility. Another possibility is that the relationship implied by our results is real. Because the IBI is designed to be uncorrelated with stream size across the region for which it is calibrated, existence of such a relationship would imply effects of one or more driving variables related to stream size, rather than size per se. Summarizing research in Iowa and other Midwestern states,

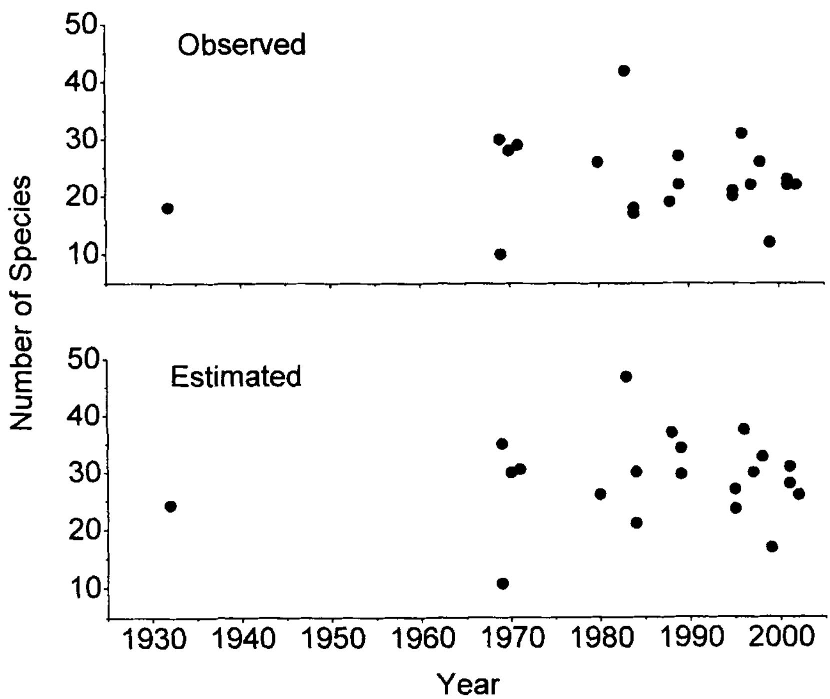

Figure 3. Observed and estimated species richness reported in individual fish assemblage surveys in streams in the upper Little Sioux River basin, plotted by survey year. Observed species richness is the actual number of species recorded. Estimated species richness was calculated using the Chao 2 estimator.

Heitke et al. (in press) concluded that good biotic integrity was associated with stable, vegetated stream banks, coarse substrates, and boulder-sized in-stream cover. In a detailed analysis of physical habitat variables in Iowa streams, Heitke (2002) reported a significant positive relationship of stream size with unvegetated, eroding stream banks and a negative relationship with substrate particle size diversity. Together, these findings suggest a linkage between habitat quality and biotic integrity that could explain the negative relationship we found between stream size and IBI in the ULSRB. Water quality differences in streams of different sizes could also play a role, but we are unaware of any studies addressing this possibility in Iowa streams.

Our comparison of contemporary and historical species richness suggested no clear trend in the number of species present in the ULSRB, nor was there any clear trend in proportions of species sensitive to environmental degradation over time. The lack of temporal trends does not necessarily imply that changes have not occurred but rather that there is no evidence for change occurring during the time period covered by our historical database. Land clearing, wetland drainage and channelization were all well underway prior to 1900, decades before the first fish assemblage survey occurred in the ULSRB (Bulkley 1975, Menzel et al. 1984, Whitney 1994, Anderson 2000), and thus it is likely that significant changes may have already occurred by the time of the first survey. Indeed, anecdotal reports from other agricultural regions in Iowa suggest the character of streams and their fish assemblages had already changed by the early 1900s (Menzel et al. 1984). Cross and Moss (1987) reported that small-stream fish assemblages in Kansas were extirpated or severely reduced in the late 1800s by conversion of the land to agriculture. Similar to our findings, Rutherford et al. (1987) found little change in southeastern Oklahoma fish assemblages from the late 1940s to the early 1980s, a time span beginning after significant land use changes had occurred. Likewise, stream fish assemblage richness changed little in Champaign County, Illinois, between 1900 and the late 1980s, although several native species were replaced by exotic species (Larimore and Bayley 1996). It is also important to remember that our historical comparisons were based solely on presence of species, not on relative abundance. It is possible that had data on relative abundance of species been available for historical surveys, we might have detected changes in the distribution of individuals of different tolerance.

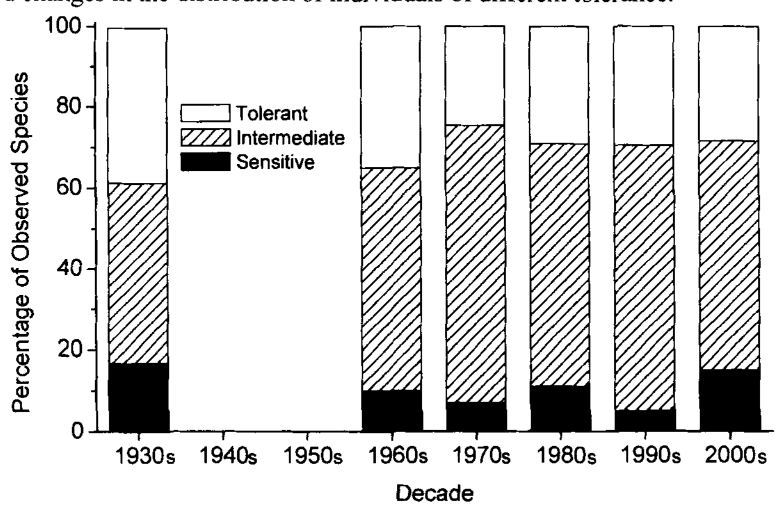

Figure 4. Percentage of tolerant, intermediate, and sensitive species collected in individual fish assemblage surveys in streams in the upper Little Sioux River basin, averaged by decade.

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