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During a 1986-87 study of microhabitat utilization by Platte River fauna we noted a persistent difference in conductance between north and south banks. A series of transects across the river, measured on 11 August 1987, between River Miles 78–59, demonstrated that the conductivity gradient persisted throughout the 32 km study segment. Typical readings were 315 umhos cm^{-1} for the north side and 550 umhos cm^{-1} for the south side. Additional upstream measurements showed that the gradient originates at the confluence of the Platte River and the Loup River Power Canal (RM 101). Upstream, the Platte River mean monthly conductivity is 922 umhos cm^{-1} while the Canal is 283 umhos cm^{-1}. Correlation analysis of the relative contribution of the Canal to total downstream discharge shows a significant negative correlation (r= -0.60; P=.0001) to the conductivity levels of the Platte River below the confluence. Occurrence of this conductivity gradient may indicate a lack of mixing of other chemical constituents in the water including pollutants.

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INTRODUCTION

Turbulent mixing in most rivers and streams leads to relatively uniform distribution of dissolved substances (Hynes, 1970). However, in some rivers the inflow of large tributaries can cause distinct lateral differences in water quality which can persist for long distances downstream (Hynes, 1970; Hall et al., 1977). The river continuum concept (Vannote et al., 1980) views the network of streams in a river drainage system as a continuum of physical gradients from headwaters to mouth. Biotic communities within this longitudinally linked physical system adapt in terms of their structural and functional characteristics. Minshall et al. (1983) suggest that deviations from this gradual longitudinal change in structure and function of stream ecosystem are largely explained by variations imposed by watershed climate and geology. These include broad scale riparian determinants, location-specific lithologic and geomorphic features, and the influence of tributaries. Water quality differences between converging rivers may be accentuated if one or both are previously impacted by impoundments (Ward and Stanford, 1983; Petts, 1984). However, within a river system impoundment tends to moderate the thermal and chemical regimes by reducing annual variations and eliminating many short term extremes.

The Platte River in Nebraska is a sand-bottomed, braided river formed by the confluence of the North Platte and South Platte rivers. Initially a small tributary to the Missouri River, it grew by eroding toward the northwest, resulting in capture of the Loup River. The Loup basin occupies approximately 20% of the State in central Nebraska (38,912 km^2) and the Loup River enters the Platte River at Columbus through two channels (Fig. 1). Upstream of its confluence with the Platte River, a large percentage of Loup River discharge is diverted into a canal (Loup River Power Canal) which runs through two power plants used for generating hydro-electric power. After passing through Lake Babcock, water from this canal enters the Platte River downstream of the Loup River confluence. Flow in the Platte is regulated by releases from impoundments built for irrigation, power generation, and flood control.

During a study in 1986-1987, while evaluating microhabitat utilization by fauna in the lower Platte River, we noted a persistent lateral difference in specific conductance. This paper describes the difference in conductance, the influence of the Loup River tributary, and discusses potential management implications.

METHODS

From June 1986 to November 1987 we measured conductivity using a portable meter and probe at study sites sampled along a 75-km segment of river downstream from Columbus, Nebraska (Fig. 2). On 11 September 1987 we measured conductivity at a series of transects between Rogers (River Mile 78) and Fremont (RM 59). Measurements were taken next to each bank, approximately 100 m from each bank, and in the center of the channel. Additional measurements were taken upstream around the confluences of the Loup River and Loup River Power Canal, and the Platte River on 15 September 1987. We compiled discharge and conductivity data for the lower Platte and Loup rivers from the 1980 to 1985 water years (October–September). We used these data to document the relative impact of the Loup River system upon the Platte River. Pearson and Spearman correlation analyses were performed using SAS programs (SAS Institute Inc., 1982, 1985). Univariate tests for normality of variables were not significant (Kolmogorov D-test, P.05) indicating that our discharge and conductivity data were normally distributed. Therefore, we elected to use Pearson correlation coefficients to describe interactions. Use of Spearman coefficients would not significantly change the relationships.

RESULTS

Twenty-eight of 31 dates had higher conductivity readings on the south side versus either the center or north side of the river. Conductivity was the same on both sides on two dates, while on only one date

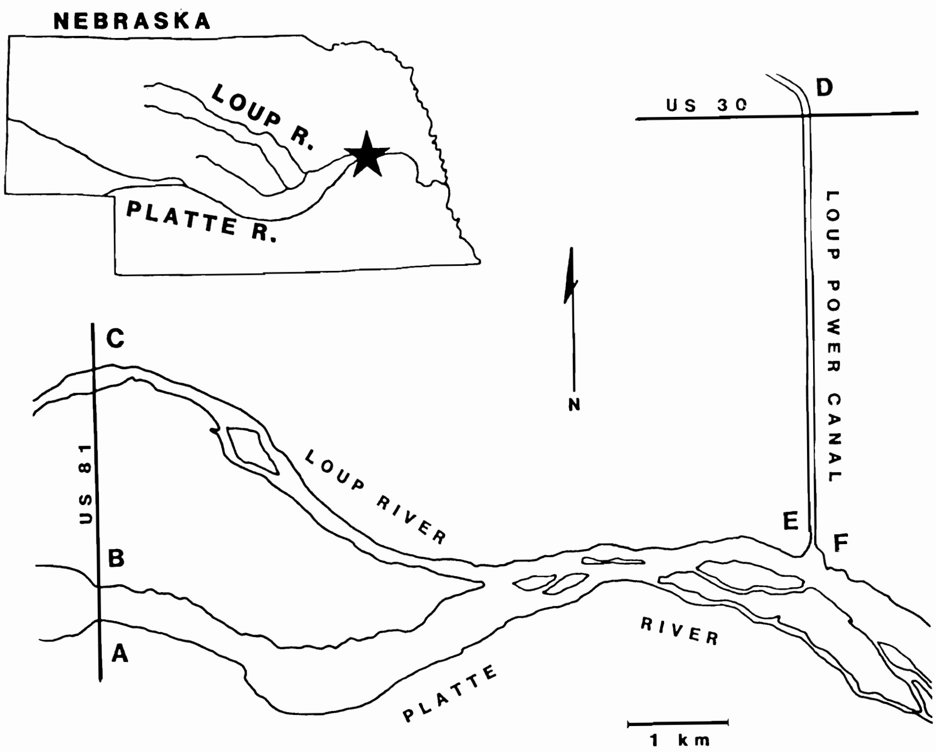

FIGURE 1. Map of the confluence of the Platte River, Loup River and Loup River Power Canal in the vicinity of Columbus, Nebraska, showing the sites (A—F) where conductivity was measured on 15 September 1987.

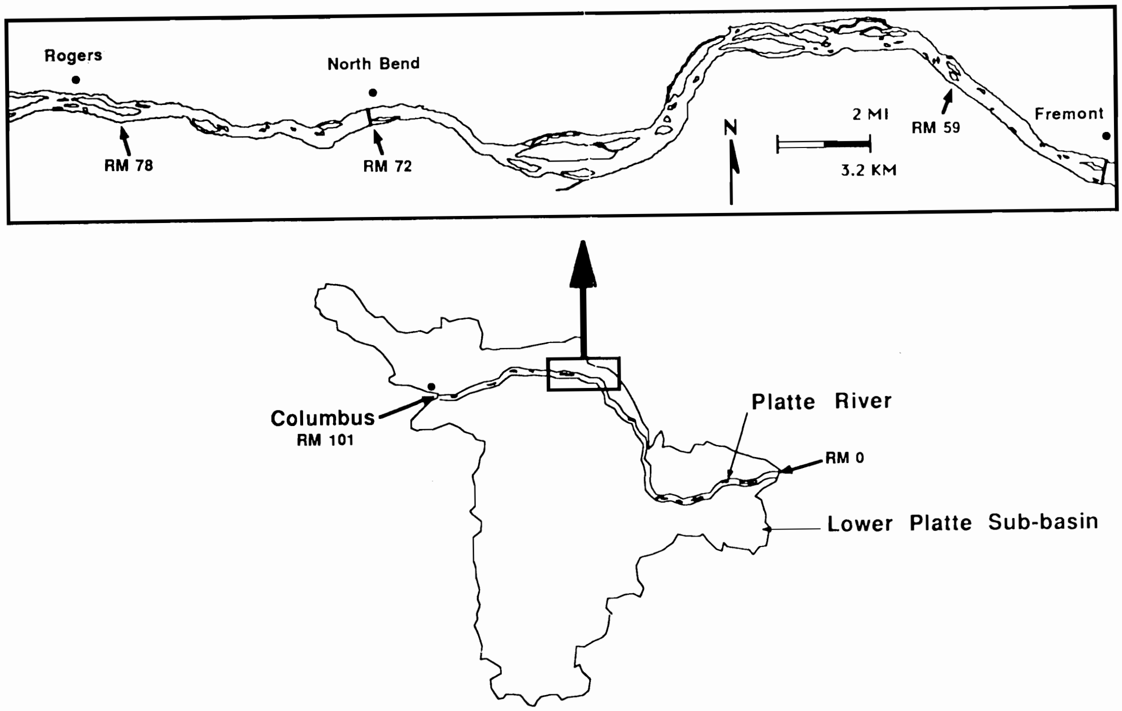

FIGURE 2. Map of lower Platte River showing the study segment between Rogers and Fremont, Nebraska.

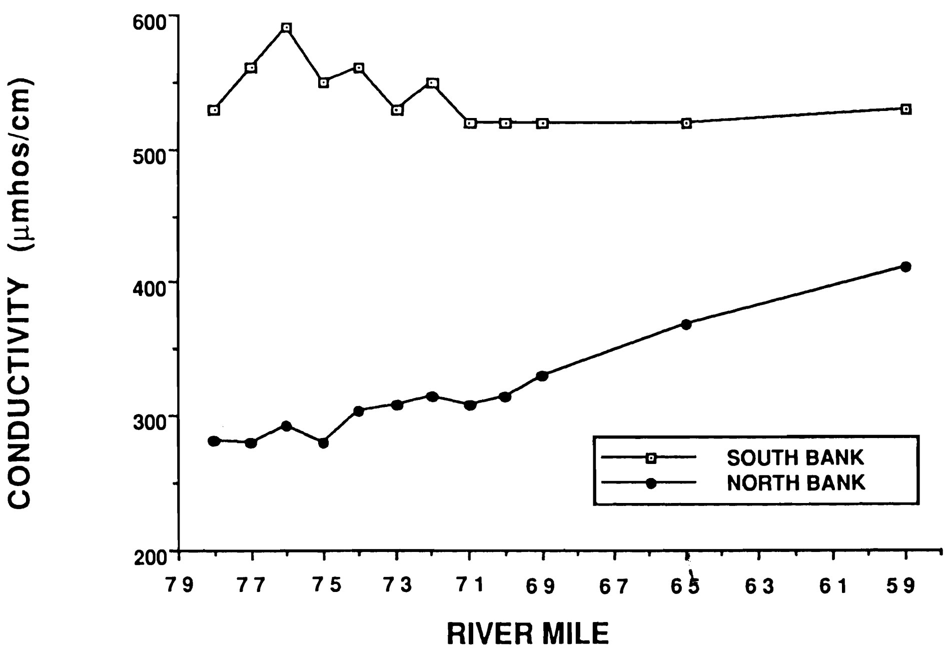

FIGURE 3. Conductivity measurements from north and south banks at sites along a 32-km segment of the Platte River, Nebraska (11 September 1987).

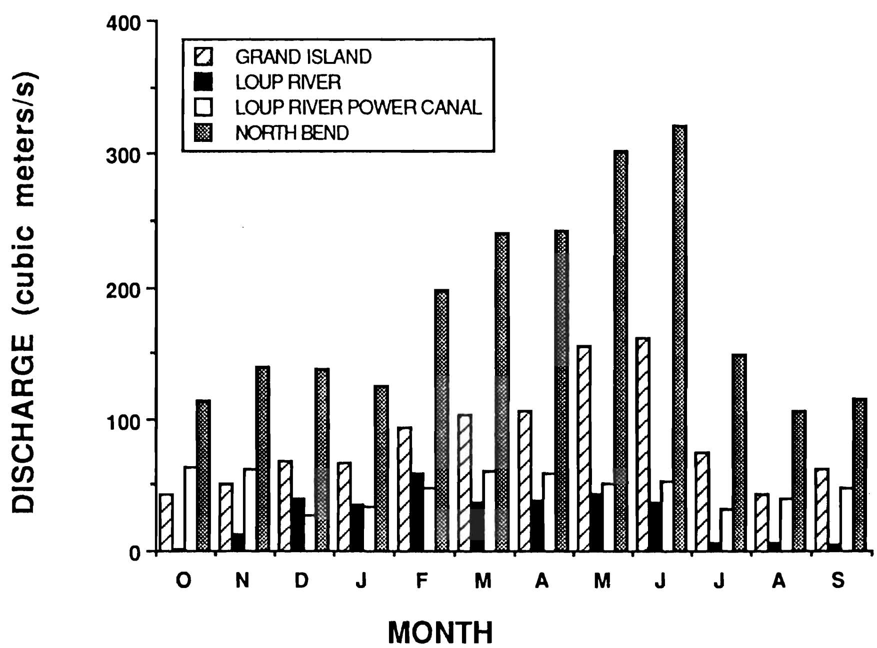

FIGURE 4. Average monthly discharge (1980—1985) measured from the Platte and Loup rivers at four places in Nebraska.

the conductivity was greater on the north side of the river. Conductivity transects taken on 11 September 1987 demonstrate a lateral conductivity gradient throughout the study segment (Table I). Within this river segment the magnitude of the lateral conductivity gradient decreases downstream (Fig. 3). At RM 78 the conductivity of the water along the north bank was approximately 53% of that found along the south bank. This difference gradually decreases downstream until by RM 59 the north side has increased in conductivity to 78% of the south side. The decreased difference is due primarily to the increased conductivity along the north side of the river while the south side remains relatively constant (Fig. 3).

To investigate the influence of the Loup River and Loup River Power Canal on the conductivity of the Platte River, conductivity readings were taken on 15 September 1987 at their confluence (Fig. 1). The conductivity of the Platte River above the confluence was 720 umhos cm^{-1} on both sides of the river (Fig. 1: A & B). The Loup River (Fig. 1: C) and Canal (Fig. 1: D) exhibited much lower conductivities, 320 umhos cm^{-1} and 230 umhos cm^{-1} respectively, before their confluence with the Platte. Readings taken on the north side of the Platte River below its confluence with the Loup River (Fig. 1: E = 470 umhos cm^{-1}) and Canal (Fig. 1: F = 230 umhos cm^{-1}) reflect the lower conductivity of the incoming tributaries. At the bridge crossing the Platte River at Schuyler (RM 86) 24 km downstream from the confluence, the conductivity on the south side was 500 umhos cm^{-1} while on the north side it was 260 umhos cm^{-1}.

Based on averages of six water-years, Loup River system discharge ranges from 39% (in both May and June) up to 69% (October) of Platte River discharge recorded 49 km downstream from Columbus at the North Bend gaging station (Fig. 4). Loup River Power Canal discharge has the greater impact, accounting for an average 22–67% of the Platte River flow, while the average Loup River discharge ranges from 2–31%. Platte River discharge above the confluence with the Loup system, measured at the Grand Island gaging station, remains relatively low throughout the late summer and fall but increases from winter to early summer (Fig. 4). Loup River discharge is relatively constant during the winter and spring but declines to near zero during summer and fall. In contrast, discharge from Lake Babcock into the Canal is more constant throughout the year.
Average monthly conductivity measurements showed consistent differences between the Platte River and Loup River over a six-year period (Fig. 5). Readings at the Grand Island gaging station upstream on the Platte River ranged from a low of 838 umhos cm^{-1} in June, up to a high of 1064 umhos cm^{-1} in February. Conductivity of the Platte River at Grand Island fell below 800 umhos cm^{-1} only three times throughout the six-year period. In contrast, conductivity of the Loup River Power Canal was relatively constant ranging from 227 umhos cm^{-1} in November to 305 umhos cm^{-1} in February (Fig. 5). Similar series of conductivity measurements are not available for the Loup River, but fragmentary data suggest that they were similar to the Canal readings. Data from the North Bend gaging station on the north side of the Platte River showed conductivity values intermediate between those in the Loup system and the Platte River above the confluence.

TABLE I. Conductivity measurements (umhos cm^{-1}) from transects along a 36-km segment of the Platte River, Nebraska (11 September 1987).

River mile	North bank	100m from north bank	Channel center	100 m from south bank	South bank
78	282	302	380	500	530
77	280	280	460	550	560
76	293	302	540	560	590
75	280	300	362	450	550
74	303	318	510	530	560
73	308	308	318	415	530
72	315	320	345	500	550
71	308	322	410	492	520
70	315	338	490	495	520
69	330	315	340	510	520
65	370	360	400	500	520
59	412	325	455	475	530

The relative contribution of Loup River Power Canal discharge to the flow of the Platte downstream at North Bend exhibited a highly significant, negative correlation with average monthly conductivity measurements taken at North Bend (r= -0.60; P<.001). However, the relative contribution of Loup River discharge showed no significant correlation with North Bend conductivity (r=0.18).

DISCUSSION

We conclude that the persistent lateral conductivity gradient observed in the Platte River below Columbus, Nebraska is primarily caused by the inflow of less conductive waters from the Loup River Power Canal and the slow mixing of these waters. Hynes (1970) notes that in some large rivers the inflow of tributary waters can cause lateral differences that persist for long distances downstream. Factors that determine the persistence of the difference include sinuosity of the channel, roughness of the bed, relative flow rates of the intersecting rivers, entry angle of the tributary, and the degree of water quality differences between the rivers. The Volga River in the USSR, the Amazon's confluence with the Rio Negro, and the formation of the Orinoco by the confluence of the Aupuro and Caroni rivers are notable examples (Hynes, 1970). As shown in Table I and Figure 3, the inflowing water of the tributary will tend to follow the bank on which it enters. Shadin (Hynes, 1970) observed this phenomenon in several rivers in the USSR. Hall et al. (1977) describe the chemical changes occurring in the Zambezi River due to the inflow of the Shire River, the ionically rich waters of which caused an increase in conductivity of 25% in the waters below its confluence.

In the Platte River, turbulent mixing of the two distinct flows is minimized by the nature of the bed material. Rolling bars of fine sand that dominate the substrate of the river and the highly braided channels promote a segregation of currents. Our data show that this conductivity gradient persists at least 75 km downstream from the confluence of the two rivers, but that the magnitude of the gradient becomes smaller as the entire channel gradually becomes mixed.

Standard chemical monitoring of the waters of the Platte River in the region just below its confluence with the Loup system is derived from monthly water samples taken from the North Bend gaging station. Water quality monitoring at this site is based on depth-integrated sample(s) taken either at the centroid of flow or at several places across a transect of the river. When multiple water samples are collected, they are composited for laboratory analyses (Engle et al., 1984). River management decisions based on these water samples may well present a biased view of water quality throughout the river channel. Chemical differences suggested by the conductivity gradient may affect biotic community structure and function from one side of the river to another. For example, plumes of pollutants may tend to retain their integrity for great distances downstream. Potential changes in the community would depend upon relative chemical tolerances and preferences of various organisms (Hynes, 1970). Until further research examines effects of this lateral chemical gradient upon the biotic community, caution must be exercised when making management inferences to the entire Platte River channel based upon

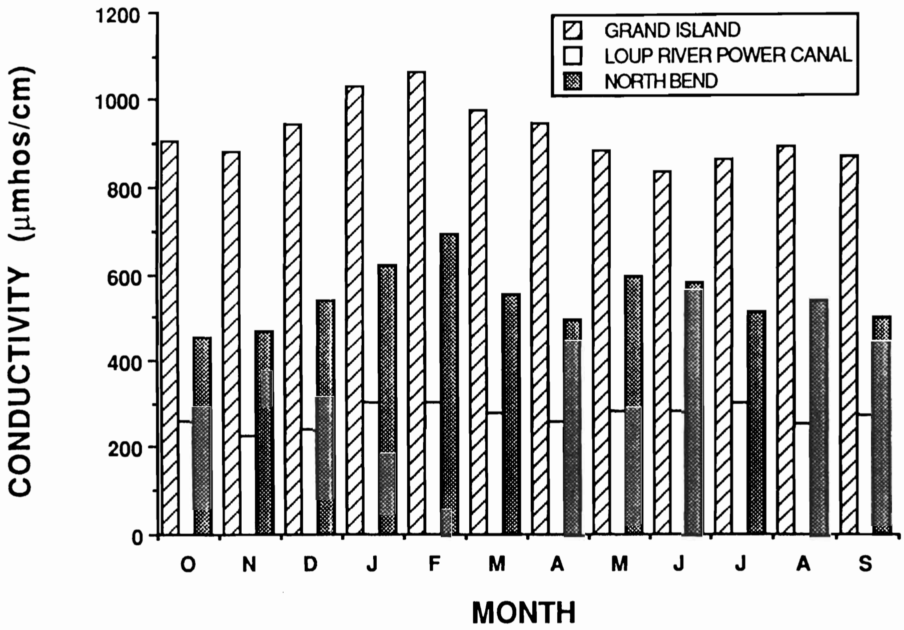

FIGURE 5. Average monthly conductivity values (1980—1985) measured from the Platte and Loup rivers at three places in Nebraska.

chemical data taken from a gaging station or a composite sample across the channel.

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