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A Relationship Between River Modification and Species Richness of Freshwater Turtles in Iowa

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Comparisons were made of turtle populations in Red Rock Reservoir and the major rivers of the Mississippi River and Missouri River drainage systems in Iowa. Of the inland rivers of the Mississippi drainage examined in this study, the Des Moines River had the least amount of remaining turtle habitat. Number of turtle species ranged from five in the Des Moines River to 11 in the Mississippi River, but only three species were found in Red Rock Reservoir. In the Missouri drainage, number of turtle species ranged from three in both the Little Sioux and Nishnabotna rivers to five in the Missouri River. Regression analysis found remaining turtle habitat to be the strongest predictor of species richness. Stream modification appeared to lower the species richness of riverine turtles by eliminating intolerant species. Intolerant forms were absent when river modification eliminated their habitat and created a more uniform and simplified environment. Map turtles (*Graptemys geographica* LeSueur), false map turtles (*Graptemys pseudogeographica* Gray), Blanding's turtles (*Emydoidea blandingi* Holbrook), and smooth soft-shells (*Apalone mutica* LeSueur), appeared to be most affected by modification. Turtle species richness was lower in Red Rock Reservoir than in the Des Moines River, possibly due to the great fluctuation in the water level of the reservoir.

INDEX DESCRIPTORS: river modification, channelization, species richness, turtles, Iowa

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Little is known about the impact of channelization and the associated modification of rivers on turtle populations. Maki et al. (1980) suggested that berm, depending on slope, may inhibit the movement of turtles when they seek nest sites away from water. In Missouri, populations of *Apalone* and *Graptemys* are thought to be declining due to channelization (Johnson, 1992). In Germany, Thienemann (1950) reported the elimination of the common European pond turtle (*Emys orbicularis* Linnaeus) from the Rhine River after regulation.

The more numerous studies of fishes suggest that channelization decreases survival of many species and subsequently decreases both abundance and species richness. For example, Simpson et al. (1982) reported that channelization impacts individual fish by affecting habitat, food, reproduction, and behavior. Bulkley et al. (1976) reported elimination of 11 species of fish from the upper Des Moines River between 1892 and 1951 when stream modification activity was most common. Paragamian (1987) found that channelized sites contained fewer fish, substantially lower standing stocks of fish, and an average lower index of biotic integrity than did natural reaches.

Iowa's rivers vary in the extent of modification they have undergone (U.S. Government, 1931; Bulkley et al., 1976). Bulkley et al. (1976) estimated stream loss for the Missouri River drainage in Iowa at 1,240 miles and for the Mississippi River drainage in Iowa at 1,775 miles. Common practices have included channel straightening, construction of levees, riprapping, and dredging. One form of stream modification common in larger Iowa rivers is construction of flood control reservoirs. These large bodies of water are centers for aquatic recreation and sport fishing. They have irregular shorelines and provide a variety of habitats with numerous bays and often receive an influx of nutrients and sediment from inflowing streams. Studies comparing reservoirs with their associated rivers provide conflicting results. Studies of phytoplankton (Chellappa, 1990) and fingernail clams (Neck, 1989) found lower diversities in reservoirs. Casado et al. (1989) found increased biomass upstream from reservoirs and Marzolf (1984) reports that diversity of native fish species is greatest at the river/reservoir interface and decreases toward the dam.

The present study examines turtle species distribution and richness among Iowa's largest rivers to test the null hypothesis that riverine turtle populations are not influenced by stream modification practices. In addition, Red Rock Reservoir turtle populations are compared with turtle populations in the associated Des Moines River and other Iowa rivers. In the examination of the impact of river modification on native turtle species richness, it appears the most important factor is not the amount of river modification but the amount of unmodified river remaining. Therefore, this additional hypothesis is tested in the present study.

STUDY AREAS

Mississippi River Drainage

Mississippi River - Sampled throughout its contact with Iowa, this is the largest river with a deep, maintained, meandering navigation channel and a series of adjacent sloughs, oxbows, and shallower lateral channels. There are numerous basking and nesting areas. Even though levees or cliffs line both sides of the river, the areas between the levees are as much as six miles wide and the gradual slopes and sandy nature of the levees provide additional nesting area above summer flood levels. Substantial additional habitat exists in oxbows on the landward side of the levees. The 11 permanent channel dams do not create fluctuating floodpools and the water levels are at least as constant as those of other Iowa rivers. Remaining turtle habitat is abundant.

Cedar River - Sampled primarily in its southern third where it meanders through a wide valley with occasional islands and a wide floodplain that contains levees only in a few places. The river has many oxbows and riverside pools with a wide variety of habitats. Remaining turtle habitat is abundant.

Iowa River - Sampled primarily in its southern third below the Coralville flood control impoundment and above its confluence with the Cedar River. Levees are common, but they are usually sandy with gradual slopes. There are many lowland areas on the landward side of the levees with abundant oxbows and pools. Remaining turtle habitat is abundant although often somewhat isolated from the river.

Des Moines River - The largest river within the boundaries of the state, the Des Moines River was sampled primarily in the southern half, southeast of Saylorville Reservoir. In many places the river is bounded by steep-walled earthen levees. Where it is not, the channel is deep with nearly vertical earthen banks, often riprapped with concrete. The occasional oxbows and pools on the landward side of the levees often dry annually as a result of drainage tiles or lowering of the water table due to deepening of the channel. There is little apparent remaining turtle habitat.

Red Rock Reservoir on the Des Moines River - A large reservoir, southeast of Des Moines, Red Rock ranges up to a mile wide and 50 miles long. Annual fluctuations of up to 40 feet in depth result in an area around the margin of the lake, known as a "bathtub ring", that is nearly devoid of vegetation. Most logs and debris that could serve as basking sites have been carried by high water to the outermost edges of the ring. The irregular shoreline where streams enter the reservoir appear to be suitable turtle habitat, although devoid of basking sites other than the rocky "bathtub ring".

Missouri River Drainage

Nishnabotna River - Sampled primarily in the southern half, especially the Riverton Wildlife Area where the east and west Nishnabotna come together. Both channels and the common channel have been straightened and deepened. There are almost no flooded oxbows ot natural riverside pools. Levees and river banks are steep and composed of black soil. There is little apparent remaining turtle habitat.

Little Sioux River - Sampled primarily in the lower half, this river has steep banks and few oxbows. The area near the Missouri River is entirely channelized and leveed. Sampling in this area included the few oxbows that retain water most years but are now isolated from the river. There is little apparent remaining turtle habitat.

Missouri River - Sampled throughout its contact with Iowa, primarily in isolated oxbows, wildlife areas, downstream from wing dams, and where streams enter the river. The entire river has been converted to a smooth channel with gentle curves and steep levees or banks. The large floodplain is now almost entirely farmed except for isolated pools and lakes, often more than a mile from the river. There appears to be moderate remaining turtle habitat, but it is often located some distance from the river.

METHODS

This study attempts to lessen the pitfalls of inconsistent sampling typical of studies based on research collections by utilizing specimens gathered in broad faunal surveys. Much of the data used in this study resulted from surveys of turtle distribution in Iowa conducted by one of the authors (JLC) during the last 25 years. Trapping was intensified in 1992 in the Des Moines River where, because of its location and size, species were expected but had not yet been found.

Turtle surveys throughout Iowa conducted by both authors utilized hand collecting, both on land and in shallow water, and modified Fyke nets (Legler, 1960) baited with fresh fish for most aquatic habitats. Trapping was concentrated during times that included the known activity periods of all species within the state (15 April - 15 July) but was sometimes conducted as late as September.

In all rivers, traps were placed in habitats most likely to yield turtles. For most species, these habitats include areas of shallow water and slow current (Ernst et al., 1994). Certain species require the presence of specific habitat conditions. For example, smooth soft-shell turtles require clean, level sandbars or sand banks for nesting (Goldsmith, 1944) and both map and false map turtles require an abundance of basking sites (Ernst et al., 1994). Early sampling revealed that turtles were rarely caught in fast-flowing, ditch-like channels with steep banks and no instream obstructions that could create areas of reduced current. Therefore, rivers typified by this kind of habitat were sampled in adjacent isolated oxbows and where creeks entered the river, creating sandbars and trash-obstructions that could provide areas of quiet water and basking sites. This was done in hope that remnant turtle populations would persist in these areas even if they were absent from the channelized parts of the river.

A trapping survey of Red Rock Reservoir was conducted throughout the spring and summer of 1992. The reservoir was sampled in protected bays and inlets where turtle habitat seemed adequate. Because of heavy human use, a few inlets were not trapped, but these did not differ in any other observable way from the areas that were sampled.

The comparisons of turtle species richness among Iowa's rivers required the use of verifiable locality records obtained prior to the present study. The collection locations of all turtles known to have been taken for Iowa were used to construct distribution maps. Turtle species richness was calculated and compared for the major rivers in the Mississippi and Missouri River drainage systems in Iowa. Approximately 90% of the specimens used in this study are found in the research collections of Drake University, Iowa State University, and the University of Michigan Museum of Zoology (Table 1). The remaining 10% of the specimens are found in the research collections of the U.S. National Museum, Field Museum, University of Nebraska, University of Utah, Coe College, Buena Vista College, and Luther College (Table 1). We examined all specimens in the Iowa collections but relied on updated identifications provided by curators of collections outside of Iowa. There were no specimens from collections outside the state that did not fit the distribution patterns established by the Drake University Research Collection, with the exception of some very early records that probably reflected shipping points rather than collection localities. Years in which specimens were collected are shown in Table 1. Species richness is expressed as the percent of possible species found to occur in each river during the course of this study. The number of "possible" species was determined by the number of species that could potentially be found in each river system at Iowa latitudes (Conant and Collins, 1991).

Table 1. Collection dates for Iowa turtle records used in this study.

Institution	% of total (n=1186)	Collection dates
Drake University	57.0	1969 - Present
Univ. of Michigan	14.6	1907 - 1956
Dr. Reeve Baily's Collection Records	13.7	1938 - 1942
Iowa State University	6.8	1923 - 1954
U.S. National Museum	5.3	1878 - 1916
Coe College	0.9	1952 - 1971
Field Museum	0.9	1941 - 1957
Univ. of Nebraska	0.5	–
Univ. of Utah	0.2	1963
Buena Vista College	0.1	1963
Totals	100	

Throughout the course of the study, attempts were made to quantify the extent of modification of individual rivers. It was discovered that no quantitative data exist detailing the number of stream miles impacted by all forms of modification (i.e. channelization, levees, riprapping, etc.). This is because much of the modification was done early in the century. For example, by 1931 the last 10 miles of the Des Moines River, before its confluence with the Mississippi River, was leveed, and most of its major tributaries channelized (U.S. Government, 1931). In addition, many smaller projects conducted by private citizens go unreported (Iowa Dept. of Natural Resources, Pers. Comm.). Some data do exist on the types of modification of major Iowa rivers. This information is summarized in Table 2.

Because no quantitative data exist on the extent of modification, for the purposes of this study, each river was assigned an index of remaining turtle habitat based on our observations while surveying each river. For example, the Mississippi River has undergone more channelization, leveeing, and dam building than any other eastern

Table 2. Summary of types of modification of major Iowa rivers.

	Straightening	Levees	Clearing & Snagging	Riprapping	Dredging	Reservoir	Source[a]
Mississippi	X	X	X	X	X	–	1, 2
Cedar	X	X	–	–	–	–	1, 2
Iowa	X	X	–	X	–	X	1, 2
Des Moines	X	X	X	X	X	X	1, 2, 3, 4
Little Sioux	X	X	–	X	–	–	1, 2
Nishnabotna	X	X	–	X	–	–	1, 2
Missouri	X	X	X	X	X	–	1, 2

[a] 1 Harlan et al. (1987) 2 Bulkley et al. (1976) 3 U.S. Government (1931) 4 U.S. Army Engineers (1975)

Table 3. Chelonian species present in major Iowa rivers and Red Rock Reservoir.

	Mississippi River Drainage					Missouri River Drainage		
	Mississippi	Cedar	Iowa	Des Moines	Red Rock Res.	Little Sioux	Nishnabotna	Missouri
C. picta	X	X	X	X	X	X	X	X
C. serpentina	X	X	X	X	X	X	X	X
A. spinifera	X	X	X	X	X	X	X	X
A. mutica	X	X	X	X	–	–	–	X
G. pseudogeographica	X	X	X	–	–	–	–	X
G. geographica	X	X	X	–	–	–	–	–
T. scripta	X	X	X	X	–	–	–	–
E. blandingi	X	X	X	–	–	–	–	–
S. odoratus	X	X	X	–	–	–	–	–
K. flavescens	X	X	X	–	–	–	–	–
M. temmincki	X	–	–	–	–	–	–	–

Iowa river, yet it retains more ideal habitat in the form of unmodified islands, bays, and adjacent oxbows than any other river in the state. For comparison, smaller rivers like the Little Sioux or Nishnabotna, which have also been extensively modified, have virtually no unmodified turtle habitat remaining. Rivers with the least remaining turtle habitat, in the form of quiet bays, inlets, and adjacent wetlands with abundant basking sites, were assigned a value of "3". Rivers with the most remaining habitat, were assigned a value of "1". These observations are noted in the descriptions of the study areas. In addition, mean water volume and distance westward, measured at the approximate midpoint of each river, were determined. Distance westward was examined because it was apparent from examination of turtle species distributions across the midwest at Iowa latitudes that the number of species generally declined toward the west. The effects of remaining turtle habitat, mean water volume, and distance westward on the turtle species richness of major Iowa rivers were tested with regression analysis using the SPSS statistical package.

RESULTS

Eleven turtle species were found in the Mississippi River drainage and five were found in the Missouri River drainage (Table 3). The westernmost river, the Missouri, had the greatest species richness of those in the Missouri River drainage, and the easternmost river, the Mississippi, had the greatest species richness of those in the Mississippi River drainage (Table 4). While these are the two largest rivers in Iowa, the third largest river, the Des Moines, had the lowest species richness in the Mississippi drainage (Table 4). The Little Sioux and the Nishnabotna rivers had the lowest species richness of any river in the state (Table 4).

Four species, which were present in other rivers of the Mississippi drainage, and thus were expected to be found in the Des Moines River, were absent from the river and from all pools sampled adjacent to it. The Illinois mud turtle (*Kinosternon flavescens spooneri* Smith) was not expected in the Des Moines River because of its narrow habitat requirements in Iowa. One species, the red-eared turtle (*Trachemys scripta elegans* Wied), was found only in gravel pits adjacent to the river about 50 miles from its confluence with the Mississippi.

Graptemys pseudogeographica was present in the Mississippi, Iowa, Cedar, and Missouri rivers, but was absent in the Des Moines River. Also lacking in the lower Des Moines was *G. geographica*, a related species found in the Mississippi, Cedar, and Iowa rivers. *Apalone mutica* was present in the Missouri, Mississippi, Cedar, Iowa, and upper Des Moines rivers. To date, no specimen of *A.mutica* has been

Table 4. Turtle species richness, expressed as percent of species possible, for major Iowa rivers and Red Rock Reservoir.

	# Species Present	Total # Species Possible[a]	Species Richness
Mississippi	11	11	100%
Cedar	10	11	91%
Iowa	10	11	91%
Des Moines	5	10	50%
Red Rock Res.	3	9	33%
Little Sioux	3	6	50%
Nishnabotna	3	5	60%
Missouri	5	6	83%

[a] Determined using geographic range maps in Conant and Collins (1991) for the species present in the two drainage systems at Iowa's latitudes.

taken from the Des Moines River south of the city of Des Moines. This is particularly interesting considering they are regularly taken by people fishing within the city limits of Des Moines. A related species, the spiny softshell (*Apalone spinifera* LeSueur), is commonly caught in the lower Des Moines River. *Emydoidea blandingi* was found in marshes adjacent to the Mississippi, Cedar, and Iowa rivers, but was absent along the Des Moines and all three western rivers, as was its marsh habitat.

Table 5. Index of remaining turtle habitat values, mean water volume, and distance westward from the Mississippi River for all rivers compared in the study.

	Habitat Index[a]	Mean Water Volume[b] (Ft^3/Sec)	Distance Westward[c] (Miles)
Mississippi	1	84,520	0
Cedar	1	4,813	67.5
Iowa	1	4,024	96.1
Des Moines	3	7,808	126.9
Little Sioux	3	858	261.9
Nishnabotna	3	1,134	242.6
Missouri	2	40,920	280

[a] Habitat index values indicate amount of remaining turtle habitat, with a value of "1" representing the most remaining turtle habitat and a value of "3" representing the least remaining turtle habitat.
[b] Gorman et al. (1992)
[c] Calculated at the approximate midpoint of each river.

A total of 70 turtles representing only three species were collected during 269 trap nights of trapping Red Rock Reservoir. *Chelydra serpentina* (Linneaus) was the most frequently caught and *A.spinifera* was captured at several locations and in large numbers at one. Most interesting was the lack of *A.mutica* in the reservoir, a species still present upstream from the reservoir in the Des Moines River. Sampling included many areas adjacent to gravel shores, habitat somewhat suitable for this species. Soft sandy shores, the preferred habitat of both *Apalone* species, were absent except for maintained swimming beaches. Surveys of basking turtles conducted throughout the spring and summer of 1992 yielded sightings on only two occasions. Only painted turtles (*Chrysemys picta bellii* Gray) were observed basking in the reservoir and no more than 10 individuals were seen basking during the sampling period.

All rivers examined in the present study were evaluated as to remaining turtle habitat and given a habitat index value based on unmodified habitat remaining. These values are shown in Table 5. The Mississippi, Cedar, and Iowa rivers were found to contain the most remaining turtle habitat in the form of unmodified bays, inlets, and adjacent wetlands and oxbows. Suitable turtle nesting areas (i.e. sandy uplands above flood levels) in close proximity to the river are also abundant. The Missouri River retains moderate turtle habitat. The channel has been straightened and the bends made less severe which tend to increase water velocity. But this has been offset somewhat by the construction of wing dams that create areas of reduced current and debris piles suitable for turtles. Old oxbows are still present in some areas and suitable nesting sites are also available.

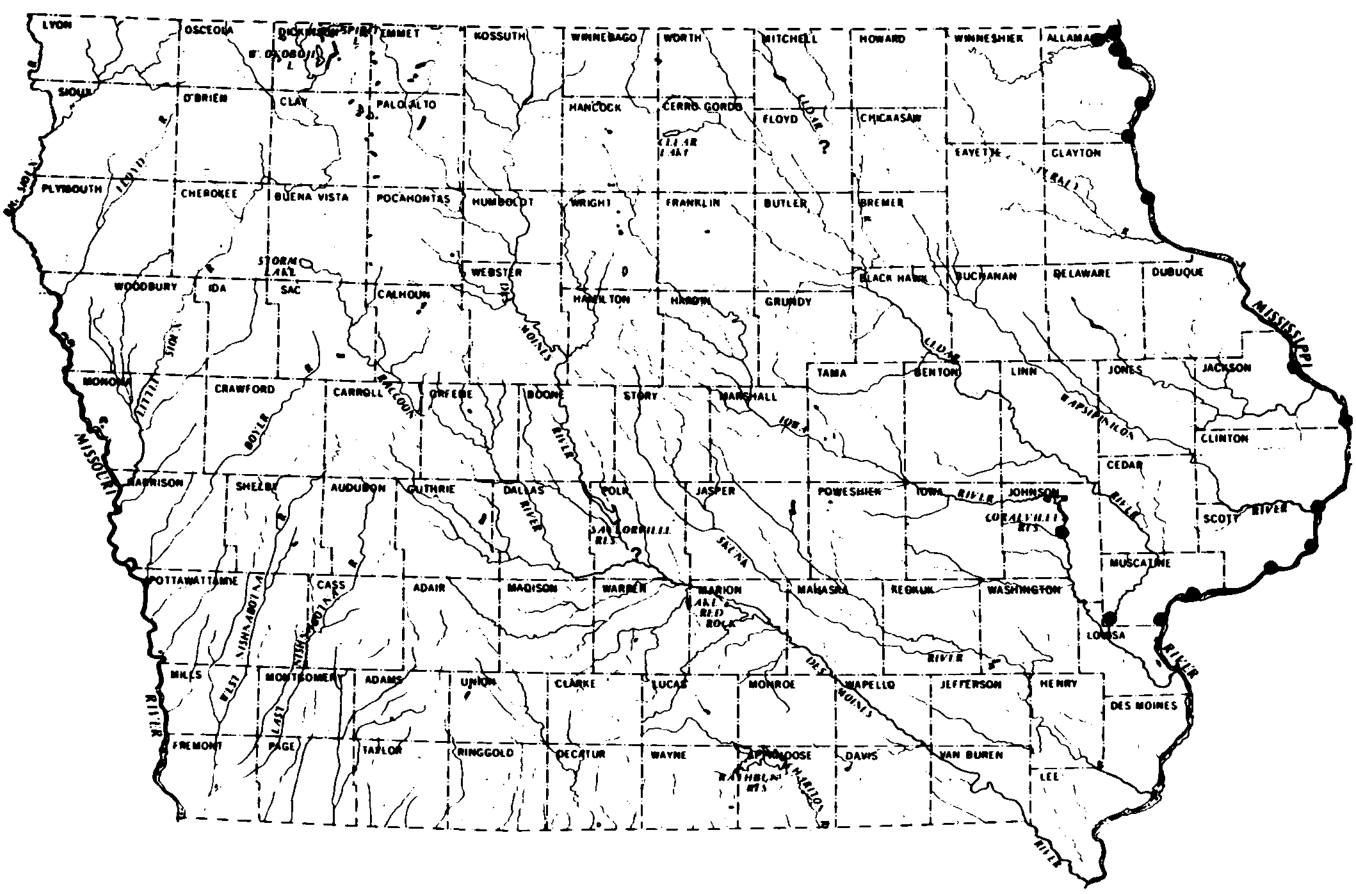

Figure 1. Collection locations for the map turtle (*Graptemys geographica*).

Table 6. Pearson's correlation coeffecients comparing species richness with remaining turtle habitat (Habitat Index), mean water volume, and distance westward from the Mississippi River.

	P Value	R Value	R^2
Habitat Index	<.001	-.95	.90
Mean Water Volume	>.10	.45	.20
Distance Westward	<.05	-.89	.79

The Des Moines, Little Sioux, and Nishnabotna rivers contain the least remaining turtle habitat. The Little Sioux and Nishnabotna rivers have straight channels, fast current, and steep-walled earthen banks. The Des Moines River also has steep banks that are often riprapped. Steep banks and riprapping may prevent turtles from reaching nesting areas. Nearly all wetlands adjacent to the rivers have been drained.

Simple regression analysis was used to study the effects of remaining turtle habitat, mean water volume, and distance westward from the Mississippi River, on the turtle species richness of Iowa's major rivers. The resulting Pearson's coefficients are summarized in Table 6. Remaining turtle habitat was found to be a highly significant ($P<.001$) predictor of species richness. Distance westward was also a significant predictor of species richness ($P<.05$), but mean water volume was not a significant predictor. Stepwise multiple regression was also used to test which variable was the best predictor of species richness. These results were entirely compatible with those obtained in simple regression analysis. Habitat index, the strongest predictor (90.8% of variance), along with distance westward (9% of variance) accounted for 99.8% of the variance in species richness. Water volume was an insignificant predictor.

DISCUSSION

Turtle species richness in Iowa's rivers decreases from east to west across the state (Table 4). The composition of any community is determined in part by the species that happen to be distributed in the area and can grow and survive under the prevailing conditions (Smith, 1980). Therefore, the decrease in species richness of turtles as one moves westward is probably largely due to natural factors influencing distribution, as is evidenced by the fact that distance westward from the Mississippi River was found to be a significant predictor of species richness (Table 6).

When rivers in the same drainage system are compared, natural factors such as climate and natural distributions play a smaller role. The decreased species richness observed in the heavily modified Little Sioux and Nishnabotna rivers located east of the Missouri is

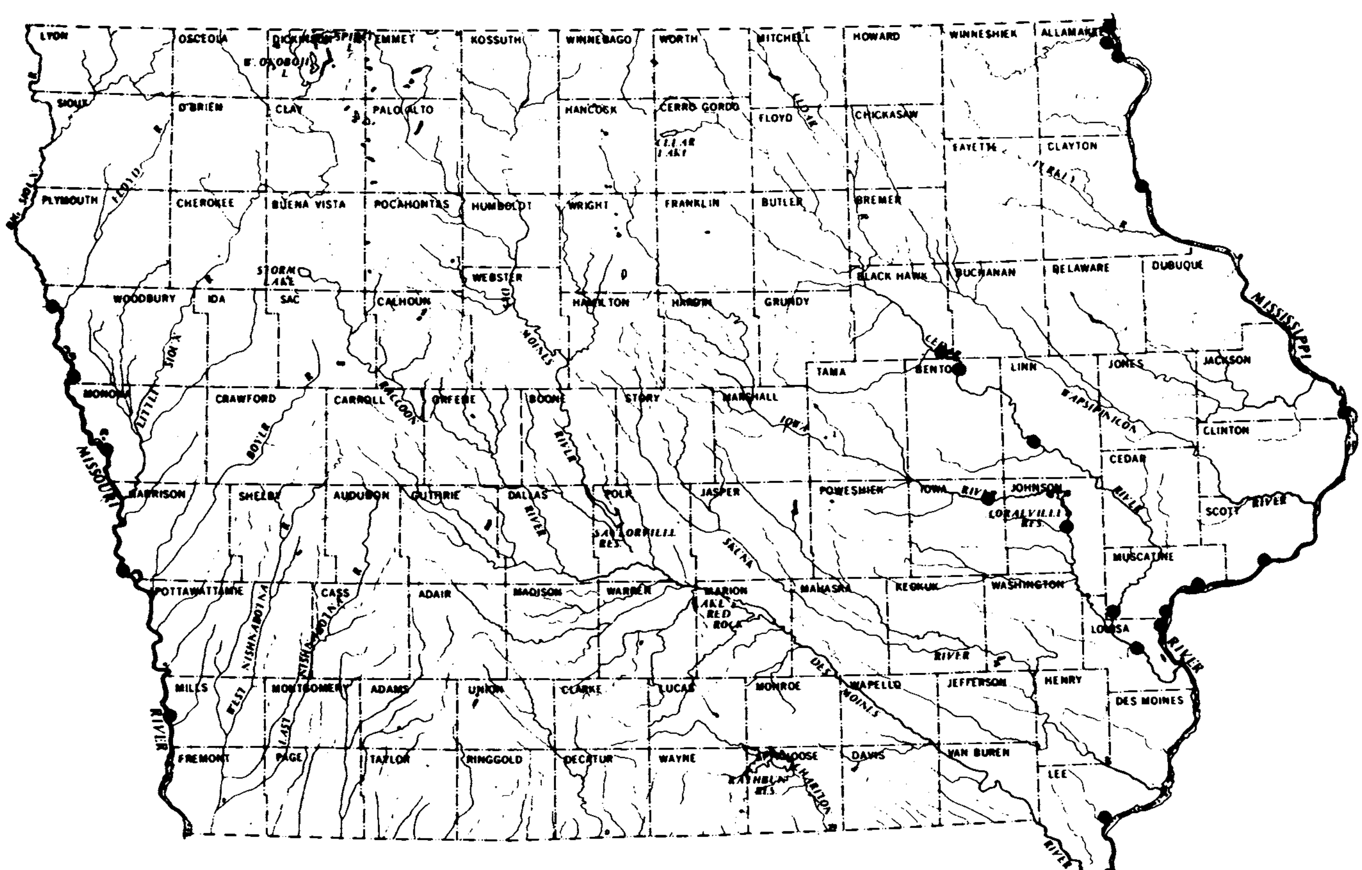

Figure 2. Collection locations for the false map turtle (*Graptemys pseudogeographica*).

obviously contrary to the established east-west trend and suggests that other factors are influencing turtle distribution. Moreover, many of the species found associated with the Mississippi drainage are southern and eastern forms, *Sternotherus* and the two *Graptemys* for example. We failed to find these in the Des Moines River even where it was south and east of the Cedar and Iowa rivers where the turtles were present.

Human activities often result in a reduction or loss of diversity within ecosystems, particularly through the loss of less common species (Patrick, 1988). Our study suggests that stream modification has lowered the species richness of riverine turtles in some Iowa rivers by eliminating intolerant forms (Table 3). Simpson et al. (1982) reported the decline of certain fish populations due to early channelization, and that these populations were replaced with forms that are more tolerant to the new habitat. Paragamian (1987) also found unusually low numbers of intolerant fish species in channelized waterways. One river, the Mississippi, appears to be an exception. While the Mississippi River has been heavily modified, the 11 channel dams create large areas of slow-moving backwater away from the main channel. The network of side channels, sloughs and small islands spread across the wide floodplain create ideal conditions for turtles, in the form of relatively stable water levels and abundant basking and nesting sites.

In most rivers, extensive modification appears to have a negative impact on turtle populations by restricting habitat. The amount of habitat remaining after modification is a highly significant predictor of turtle species richness (Table 6). The explanation for lower species richness in highly modified rivers appears to be a reduction in habitat diversity, creating a more homogeneous and simplified environment. Channelized streams lack many of the characteristics that create habitat diversity (Bulkley et al., 1976; Paragamian, 1987; Simpson et al., 1982).

The data in this study suggest that *G. geographica* (Figure 1), *G. pseudogeographica* (Figure 2), *A. mutica* (Figure 3), and *E. blandingi* (Figure 4) are particularly affected by stream modification. Not only are they missing from the lower Des Moines River, but are also absent from the Little Sioux and Nishnabotna rivers in western Iowa, all of which have undergone extensive modification (U.S. Government, 1931; Bulkley et al., 1976; Harlan et al., 1971). Conant and Collins (1991) report that populations of several species of *Graptemys* have been severely decimated by the channelization of many southern rivers. Johnson (1992) also suggests that *Apalone* and *Graptemys* populations are declining in Missouri due to siltation and channelization.

All of these species have specific and unique habitat requirements that are often no longer present after modification. *Graptemys geographica* and *G. pseudogeographica* are shy species that inhabit slow moving rivers, river sloughs, and oxbow lakes (Ernst et al., 1994). Both are also confirmed baskers, requiring an abundance of basking sites (Ernst et al.,1994; Johnson,1992). *Apalone mutica* bask almost entirely on sandy or muddy beaches, or in shallow water associated

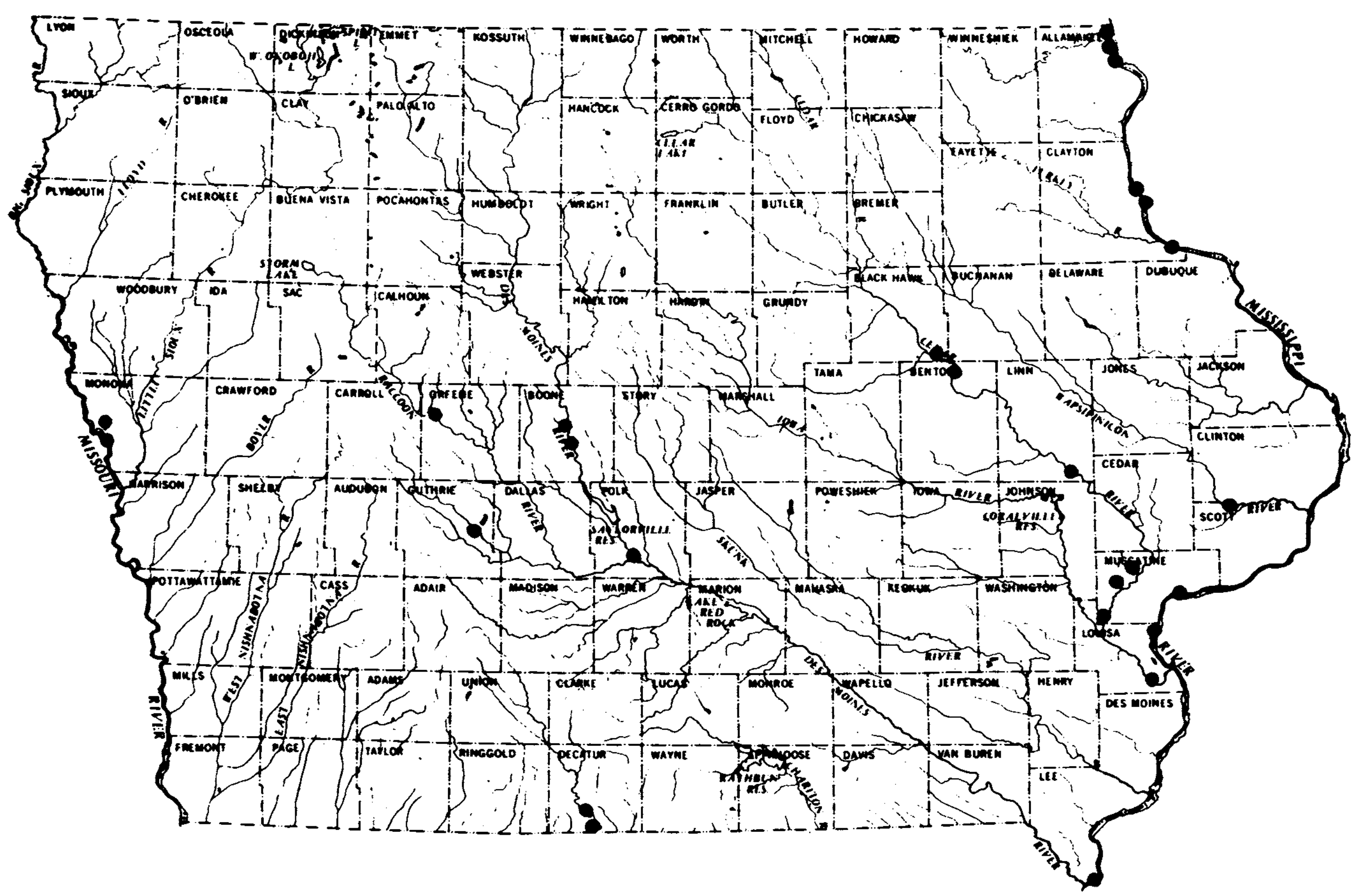

Figure 3. Collection locations for the smooth softshell (*Apalone mutica*).

with such beaches (Williams and Christiansen, 1981). In addition, they prefer to nest on clean, level sandbars or sandy shores that are free from weeds, trash, and sediments (Goldsmith, 1944). In Iowa, *E. blandingi* are restricted to the vicinity of marshes, sloughs, or quiet river bays were water is less than four feet deep and emergent vegetation is dense (Christiansen and Bailey, 1988). Nearly all of this type of habitat along the Des Moines, Little Sioux, and Nishnabotna rivers has been drained to provide more land for agriculture.

Certain species do not appear to be affected by river modification, for example, the ubiquitous snapping turtle (*C. serpentina*) (Figure 5). These tend to be fairly tolerant species able to adapt to a wide range of habitat conditions.

Red Rock Reservoir had surprisingly few species and a surprisingly low abundance of the species that were present. It appears to support fewer species than the Des Moines River, either below ot above the reservoir. We believe that this is due to the extreme fluctuations in water level that occur throughout the year. The U.S. Army Corps of Engineers (1991) reported that the natural resources of Red Rock Reservoir are impacted by lake level fluctuations. The highly fluctuating water levels of the reservoir create unstable conditions that eliminate all but those species that appear to be the most tolerant and are able to adapt to an environment that is constantly changing. Platt (1973) made similar observations comparing the vertebrate communities of Coralville Reservoir and Cone Marsh.

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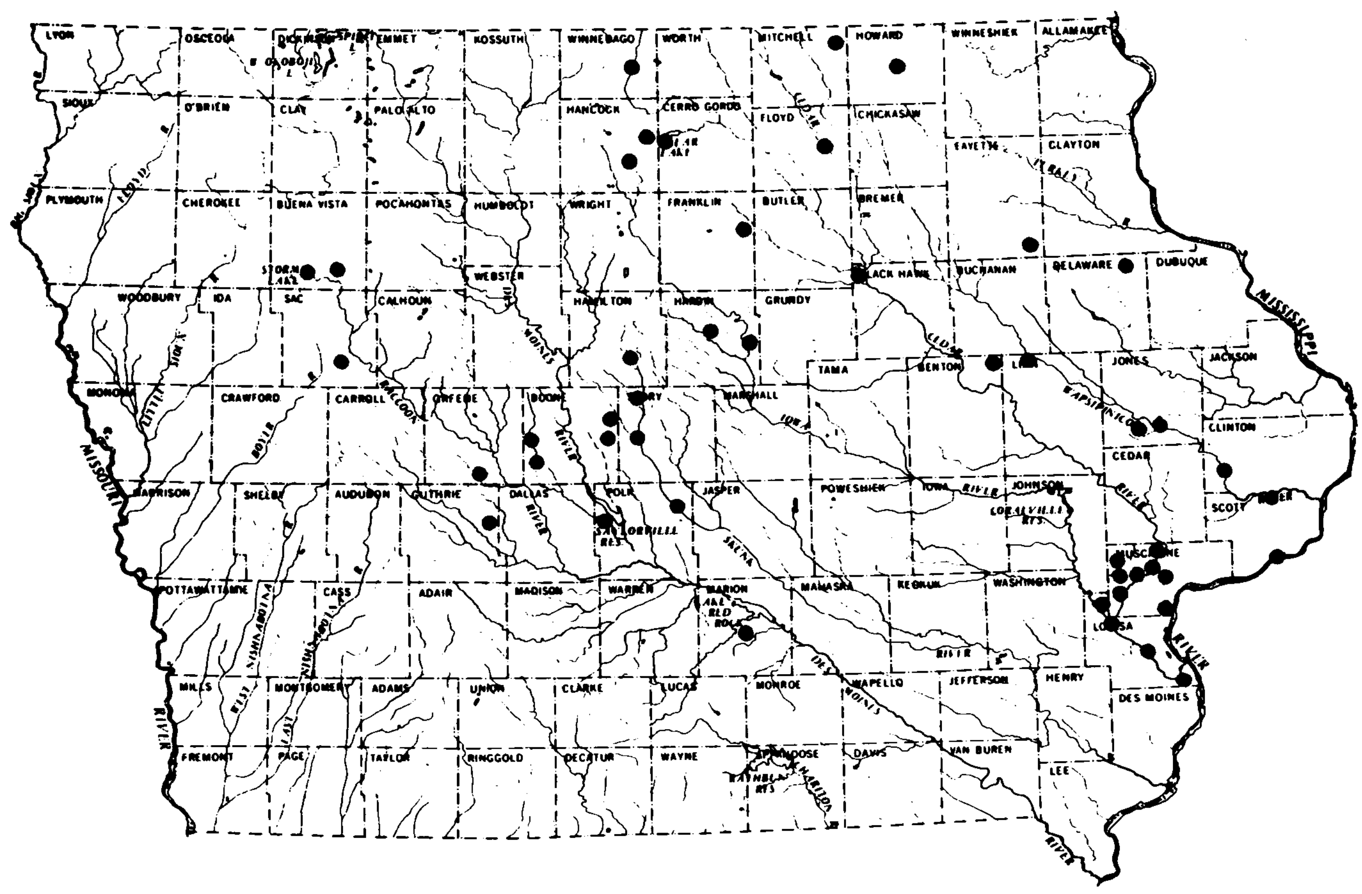

Figure 4. Collection locations for the Blanding's turtle (*Emydoidea blandingi*).

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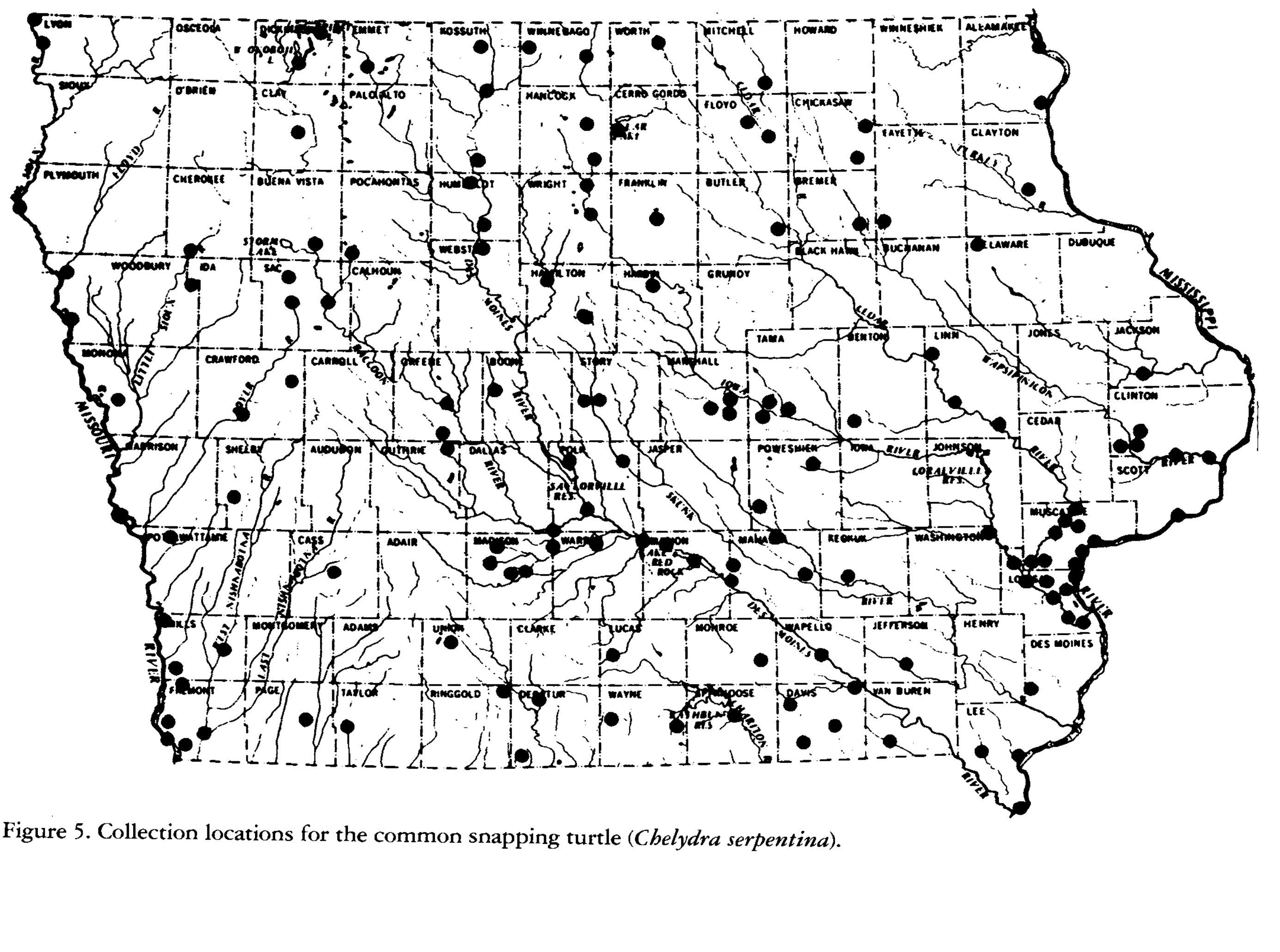

Figure 5. Collection locations for the common snapping turtle (*Chelydra serpentina*).