Impact of Euro-American settlement on a riparian landscape in northeast Iowa, midwestern USA: an integrated approach based on historical evidence, floodplain sediments, fossil pollen, plant macrofossils and insects*

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Abstract: European settlement and attendant forest clearance and agricultural activities in northeastern Iowa caused changes in the landscape, vegetation, insect fauna and water quality unequalled in rate and magnitude since the melting of Wisconsinan glaciers. Historical documents show that the upper part of the Roberts Creek drainage basin was settled between AD 1840 and 1856, and the area was under intensive cultivation by 1880. Extensive soil erosion beginning at this time resulted in increased runoff and more frequent flooding; aggradation rates increased by one to two orders of magnitude over those in presettlement times, and the entire floodplain was covered with up to 1 m of sediment. Channel widening between about 1880 and 1930 allowed the stream to accommodate greater floods, overbank deposition decreased, and further deposits were restricted mostly to the channel belt.

The presettlement vegetation was a stable mix of wet meadows and riparian shrubs on the floodplain, a rich aquatic community in the stream, and oak savanna on the valley walls and upland. Disturbance from soil erosion, floodplain erosion and floodplain deposition almost completely replaced both lowland and upland communities with ruderal (disturbed ground) plants, many of them introduced weeds. Regional insect communities were simultaneously affected by changes in land use. The presettlement aquatic beetle fauna was dominated by species of dryopoid beetles that today inhabit only streams of high water quality. Terrestrial beetle taxa included species of undisturbed grasslands and riparian forest. The changes in the landscape resulted in a decrease in the diversity of terrestrial beetle taxa and caused the near total elimination of dryopoid beetles in stream waters. Dominating the historic assemblages are beetles associated with dung, polluted waters and cultivated plants, including host-specific immigrant beetle species that are associated with immigrant plant species.

Key words: Euro-American settlement, human impact, riparian landscape, cultural landscape, historical evidence, floodplain sediments, pollen, macrofossils, insects, Iowa, midwest.

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Introduction

What impact have land settlement and modern agriculture had on natural landscapes? This question is difficult to answer, because (1) these changes in land use occurred over a century ago in the US, and (2) those remaining natural landscapes in the midwest cannot be tested because they are already affected by such anthropogenic factors as increased runoff and pesticide drift from surrounding areas. However, some of the impacts of agriculture on natural landscapes can be evaluated by comparing presettlement and postsettlement fossil and lithologic records that include the last few hundred years. These records reflect changes in land-use practices and have been used to document some of the resulting impacts on the environment. The purpose of this paper is to illustrate how Euro-American settlement changed the character of the landscape, stream behaviour, vegetation, beetle fauna and water quality in a small northeastern Iowa drainage basin.

The record preserved in the Roberts Creek Basin in northeastern Iowa (Figure 1) shows how significant and interrelated the effects of historic land-use changes were on vegetation, slope processes, hydrology, sedimentation and water quality. These changes affected all parts of the landscape to varying degrees, but nowhere was the impact greater than on the floodplain. In order to evaluate the nature of historic floodplain changes, we examined historical documents, Holocene stratigraphy beneath the valley floor, average floodplain aggradation rates, and aspects of the palynology, plant macrofossils, beetles and chemistry of presettlement and historical deposits. We used sites ranging in age from about 3000 BP to the present. The historical deposits are recognized by: (1) sediment stratigraphy, (2) the abundance of plant macrofossils and beetles of introduced species, (3) radiocarbon dates, and (4) the presence of recent artifacts such as barbed wire, glass, bricks and other debris. The historical data reveal the nature and timing of floodplain changes, and the record from about 3000 BP to settlement time provides baseline information for assessing the changing edaphic and ecologic conditions during this period.

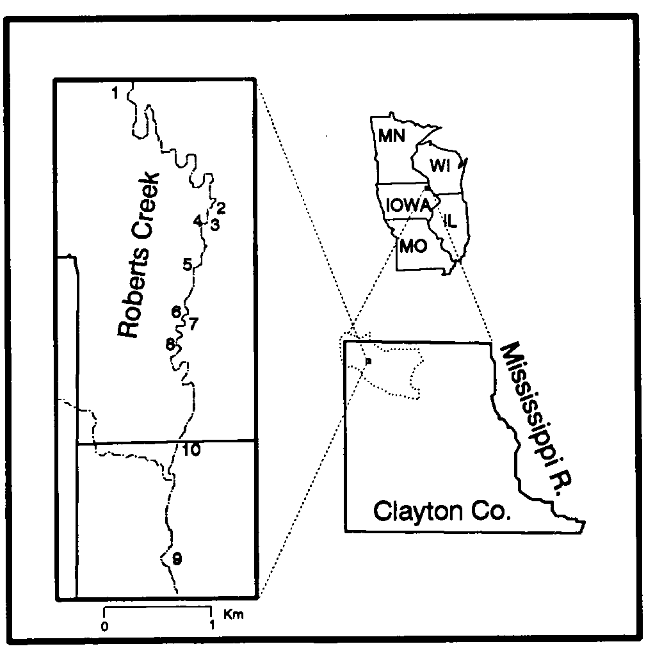

Figure 1 Location map. Area outlined in Clayton County is the Roberts Creek drainage basin. Uncalibrated radiocarbon ages of sediments at numbered sites are as follows: 1 = modern; 2 = 150 BP; 3 = 1820 BP; 4 = 2850 BP; 5 = 380 BP; 6 = 70 BP; 7a = modern; 7b = 2350 BP; 8 = 1220 BP; 9 = 2900 BP; 10 = modern (see Table 1).

The environmental impact of aboriginal agrarian activities during the Neolithic was relatively slight, but it is recognizable in pollen diagrams from Europe, the Middle East and Japan (Tsukada, 1972; Birks *et al.*, 1988). Even in North America, similar small changes from native American agriculture are noticeable (Delcourt *et al.*, 1986; McAndrews, 1988). These effects are generally: (1) slight decreases in pollen of forest taxa, suggesting that forests were cleared for agriculture, (2) slight increases in pollen percentages of crop species that were planted, and (3) increases in pollen of disturbed ground plants, which became established on the newly cleared areas and abandoned fields and gardens. The changes in landscape and vegetation were apparently slight because only small areas were affected and the changes occurred slowly over a relatively long time.

In contrast, European settlement in North America caused rapid and consequential changes in the environment over a large region. A rise in *Ambrosia* (ragweed) pollen percentages of 2–10 times presettlement values is the most widely known marker for the settlement horizon in the eastern and central United States (Webb *et al.*, 1983), and increases in sedimentation also occurred following cultivation (Knox, 1987). However, these studies only hint at the total changes in the ecosystem and landscape as a consequence of settlement. Such changes, as documented in the biotic, sedimentary, pedological and historical record, have rarely, if ever, been studied simultaneously in a drainage basin.

Many previous studies in North America that documented impacts of changes in land use have concentrated mainly on lake sediments (Davis, 1973; 1989; Birks *et al.*, 1976; Maher, 1977; Bradbury and Waddington, 1973; Brugham, 1978). For example, Birks *et al.* (1976) compared the fossil and chemical content of pre- and posthistoric lake sediment in lakes in northwestern Minnesota. At Lake Shagawa, northern Minnesota, Bradbury and Waddington (1973) related changes in lake chemistry and biota to human activities, including mining. Davis (1973), Maher (1977) and Brugham (1978) showed increased sedimentation rates in lakes ranging in size from small ponds to Lake Superior, caused by various human activities. Some recent studies have shown the relationship between human activities and stream behaviour. Knox (1987) related changes in sedimentation in stream valleys in southwestern Wisconsin to mining and other human activities, and James (1991) showed changes in stream channel morphology that were related to hydraulic mining in California.

The impact of Euro-American settlement on the insect fauna of North America was as profound as that caused by any event in the late Quaternary, including glaciation. Populations of insect species representative of such habitats as forest, native prairie and marshlands were replaced by ruderal species as extensive deforestation, cultivation and drainage of wetlands accompanied the westward expansion of Euro-American settlement (McLeod, 1980; Turnbull, 1980). Associated with settlement was the accidental or intentional introduction of exotic insect species (Lindroth, 1957; Sailer, 1983). For example, of the 1683 immigrant arthropod species reported by Sailer (1983) in the continental United States, 66% originated from the western palaearctic region.

The study of beetle remains from archaeological sites has become a well established discipline in Europe (e.g., Buckland and Kenward, 1973; Osborne, 1974; 1988; Kenward, 1976). In North America, however, such studies are only now being initiated (e.g., Elias, 1986; 1990), and none until now has examined anthropogenic changes of an insect fauna. The discovery of a rich assemblage in northeastern Iowa permits a palaeontological examination of the impact of human activities on the species composition of the regional beetle fauna.

Roberts Creek is well suited for studying the effects of agricultural land-use change. Modern vegetation near the study area is mostly pasture on the floodplain and row crops on the uplands, with a few scattered groves of oak. The low permeability of the Ordovician shale that underlies the floodplain has kept the water table at a relatively stable position within the Holocene alluvial fill for the last 12500 years (Bettis, 1984). The creek has meandered across the valley floor throughout the Holocene with little downcutting and only modest aggradation, and numerous beaver-dam ponds, small abandoned channel ponds, and point bars were formed, rapidly buried with sediment, and later exposed by lateral stream migration. These exposures in the creek banks and cores collected from the valley floor are the sources of fossil data. Fossil preservation is excellent, because deposition was rapid and the water table was continuously high. The area sampled is near the headwaters of the basin, guaranteeing that the fossils are of local origin. Over 40 sites spanning the entire Holocene were sampled along the creek. Sixty-one radiocarbon dates, 53 of which were on wood, provide a reliable chronology and indicate that each deposit represents only about 100 to 200 years of accumulation (Chumbley, 1989; Chumbley *et al.*, 1990). Of the 40 sections studied, ten date from the last 3000 years and are the basis of this study.

Historical information

Conditions at the time of settlement can be approximated from notes recorded during the General Land Office Survey of Wisconsin Territory (1837–1849). At that time, large prairie tracts occupied most upland and gently sloping areas, while timber was restricted to a narrow belt along the Roberts Creek channel. Human impacts were minimal; a military road traversed the northeastern part of the basin, three small fields were present in the basin's northeastern uplands, and there was a single field on the divide near the junction of Deer and Roberts creeks, within the reach of the valley where our study sites are located. The 1838 census of Wisconsin Territory supports this image of few inhabitants; a population of 274 is recorded for Clayton County, most of whom lived by the Mississippi River. Soon thereafter Euro-American settlement increased markedly. The population of Clayton County was 500 in 1840 and 1000 in 1850. By 1856 more than 1000 people, mostly farmers, lived in Roberts Creek basin alone (Iowa State Census, 1856), and by 1880 a large percentage of upland and broad valley tracts in the basin was in wheat, maize and hay (Benton and Gray, 1925).

Knox (1987) used historical records along with a variety of sedimentological tracers derived from mining operations to evaluate the timing of floodplain aggradation during the historical period in southwest Wisconsin. He concluded that tributary valleys aggraded primarily between about 1890 and 1930. After that time the meander belt expanded, and sedimentation decreased sharply outside the meander belt. Although we are not able to date precisely the period of historical sedimentation because these age tracers were not available in the Roberts Creek drainage basin, a similar chronology is likely. One line of evidence that supports the idea that historical sedimentation was nearly completed by the 1920s in the Roberts Creek study area is that soils mapped in this part of the valley in the 1920s were noted to be 'well above overflow' (Benton and Gray, 1925).

Methods

Deposits exposed in stream banks along Roberts Creek were measured and described using standard procedures and nomenclature (Soil Survey Staff, 1975). Deposits were also examined in 7.6-cm-diameter cores taken with a drill rig. Coring transects and bank exposures were used to determine the thickness of historical alluvium across the valley floor.

Samples for radiocarbon dating were collected from stream banks and cores. All samples were analysed by Beta-Analytic, Incorporated, and the ages reported are uncorrected except as noted (Table 1). Samples for pollen, macrofossils and insects were dug by hand from cut banks along Roberts

Table 1 Radiocarbon ages of samples reported in this study. Site numbers refer to locations on Figure 1

Site no.	Material dated	^{14}C date	Laboratory no.	Biota present*	Comments
1	–	None		m, b	Surface sample from channel
2	Wood	70 ± 50	Beta-21154	m, b	Presettlement, no introduced species – date arbitrarily set at 150 BP
3	Wood	1820 ± 70	Beta-7402	p, m, b	
4	Organics	2850 ± 90	Beta-7400	m	
5	Wood	380 ± 70	Beta-7401	m	
6	Wood	(105 ± 0.6‰)	Beta-29108	p. m. b	Barbed wire dates ~AD 1880
7a	Wood	2480 ± 180	Beta-31924	p, m	
	Wood	2330 ± 90	Beta-31922		
	Wood	2230 ± 50	Beta-31923		
7b	–	None		m, b	Surface sample from abandoned channel
8	Wood	1220 ± 70	Beta-7397	p, m	
9	Wood	2890 ± 60	Beta-14230	p, m	
	Wood	2860 ± 70	Beta-14229		
	Wood	2840 ± 70	Beta-14232		
	Wood	3000 ± 70	Beta-7295		
10	–	None		b	Surface sample from meander abandoned in AD 1964

Note:
*p = pollen, m = macrofossils, b = beetles.

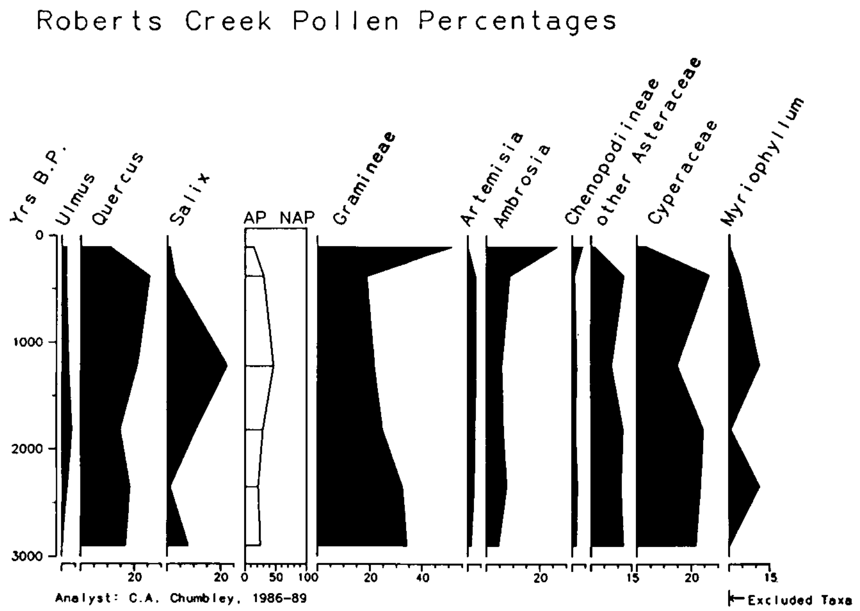

Figure 2 Pollen diagram constructed from six sites showing ten selected pollen taxa.

Creek. Approximately 300 cm^3 of matrix were collected for pollen and macrofossil analysis and about 20 kg for insect analysis at each site. Pollen samples were processed following Fægri *et al.* (1989) using KOH, HCl, acetolysis and HF. In addition, the sediment was sieved through a 7 μm screen (Cwynar *et al.*, 1979), treated with 10% sodium hypochlorite solution and floated using ZnCl (Chumbley, 1989). Pollen was mounted in silicone fluid, and at least 300 pollen grains were counted in each sample. Plant macrofossils were sieved using 0.5- and 0.105-mm screens, and wet residues were hand picked. Samples were stored in glycerin with a pinch of phenol as a preservative. Pollen and macrofossils were identified using reference collections at the University of Iowa Geology Department and are preserved in the repository there. Plant nomenclature follows Gleason and Cronquist (1963).

Not every sample was analysed for all biotic elements. Ten sites have macrofossil analyses, whereas pollen and insects were analysed from six sites. The uppermost sample on the pollen diagram (Figure 2) is from historical sediments (site 6 on Figure 1) of about 1880 BP; the uppermost macrofossil samples are from modern abandoned channel sediments. Bulk samples of the sediment were processed for fossil beetles according to procedures described in Ashworth (1979). The beetle remains (mainly heads, pronota and elytra) are disarticulated but otherwise well preserved. They are reposited on microslides and in vials at the Quaternary Entomology Laboratory, North Dakota State University, Fargo, North Dakota. Grain size composition of the deposits was determined using the pipette method (Walter *et al.*, 1978). Organic carbon, total nitrogen and total phosphorous contents were determined at the Iowa State University Soil Survey Laboratory using standard methods (Dick and Tabatabai, 1977; Yeomans and Bremner, 1991).

Results and discussion

Characteristics of historical alluvium

Historical alluvium in Roberts Creek basin is similar to that found in other parts of the upper Midwest (Magilligan, 1985; Bettis and Littke, 1987; W.C. Johnson, 1987; Knox, 1987; Bettis, 1990). It consists primarily of very dark greyish brown (10YR3/2) to dark brown (10YR4/3) planar bedded silt loam and loam resting abruptly on the very dark grey (10YR3/1) to black (10YR2/1), a horizon of the presettlement surface soil (usually a mollisol). Bedding is usually absent in the upper few decimetres of the postsettlement deposits because sedimentation was slow or intermittent, allowing sufficient time for bioturbation and other pedogenic processes to destroy former bedding structures.

The thickness of historical alluvium varies across the valley floor. Within the modern channel belt, the thickness of the fine grained increment of the historical alluvium is extremely variable, ranging from <10 cm to 2 m. Outside the channel belt its thickness averages 1 m where it buries Holocene alluvium younger than about 3500 BP and 44 cm where it buries older Holocene alluvium. The surface of these buried deposits ranges from 0.5–1.5 and 1.7–2.4 m above the adjacent channel bed, respectively. Low terraces underlain by alluvium older than about 8000 BP are usually elevated more than 2.5 m above the adjacent channel bed and have little or no cap of historical alluvium. Knox (1987) found similar relationships among thickness of historical alluvium, age of the underlying presettlement deposits, and relative elevation of the presettlement surface in the Driftless Area of Wisconsin. Historical alluvium is also found at the base of valley wall slopes where it varies from a few cm to 50 cm in thickness. In a few places 1–2 m of historical alluvium were recorded beneath small alluvial fans emanating from steep, healed gullies on valley slopes.

Calculation of average sedimentation rates (from observations at more than 50 sites) using an age of 150 years for the base of the historical alluvium, and radiocarbon ages for late Holocene and early to middle Holocene-age alluvium indicates that aggradation increased from presettlement rates of 0.028–0.13 cm $year^{-1}$ to an average of 0.7 cm $year^{-1}$ in the historic period. The presettlement values are comparable to those obtained by Knox (1987) in streams of similar size in Wisconsin's Driftless Area, but the historic values from Roberts Creek are higher than those from the Driftless Area. If most of the historical alluvium accumulated in the 40 years between AD 1890 and 1930, as suggested by historical records, then the historic sedimentation rate is even higher, about 2.6 cm $year^{-1}$.

The organic carbon content of historical alluvium is slightly lower than that of the upper, humus-rich A horizon of the buried presettlement soil, but significantly higher than that of the presettlement alluvium beneath the A horizon. These differences probably reflect the origin of a significant part of the historical alluvium from erosion of the upper, organic-rich part of soil profiles in the watershed. The contrast between the organic carbon content of historical and presettlement alluvium is not as great for deposits dating from 3500 BP or later (the presettlement floodplain) as it is for older alluvial deposits (presettlement low terraces). Total nitrogen relationships parallel those of organic carbon. Total phosphorus content is much lower in historical alluvium than in late Holocene alluvium, but similar to that of early and middle Holocene alluvium and the upper horizons of loess-derived upland and valley slope soils. The chemical properties of historical alluvium are consistent with an interpretation that the unit was derived primarily from erosion of the upper solum (A, E and upper B horizons) of prairie/forest transition (Mollic Hapludalfs) and forest (Typic Hapludalfs) soils in the Roberts Creek drainage basin.

Three phases of change in historical valley floor hydrology and sedimentation are evident. The first occurred during the early settlement period and involved land clearing and initial cultivation. The amount of land in cultivation was small at the beginning of this period, but increased dramatically in the 1850s. Initially the deep, organic-rich prairie and prairie–forest transitional soils of the upper part of Roberts Creek basin continued to provide relatively good infiltration, so that runoff remained relatively low. Experimental studies indicate that the original vegetation and porous, humus-rich presettlement top soil were extremely effective in retarding surface runoff and sediment yield (Sartz, 1975; 1976). However, after several years of cultivation with poor conservation practices, the infiltration capacity of the soils in the basin decreased, and the increased runoff began to reach the channel network. In the last decade or two of the nineteenth century the second phase began, as flood peaks and sedimentation increased significantly because poor conservation practices intensified soil erosion and augmented runoff. Frequent flooding and relatively rapid floodplain aggradation continued until sometime in the 1920s or 1930s, then began to decrease as the channel adjusted to the changed hydrologic conditions by widening. At that time the meander belt expanded, less of the valley floor was flooded, and floodplain sedimentation decreased. During the final stage, runoff and sediment delivery to the valley decreased as a result of the adoption of better soil and water conservation practices. This final phase of valley floor changes has been characterized by decreased valley floor sedimentation, lower peak flood height, and maintenance of a relatively wide channel.

Plants

Pollen analysis of the cut bank and core sediments shows that the presettlement vegetation pattern was established in the area about 3000 BP (Figure 2; see also Chumbley *et al.*, 1990). Land survey records from the 1830s and 1840s (Chumbley, 1988; unpublished data) indicate that oak savanna occupied much of the Roberts Creek basin. Prior to settlement the major pollen types present were *Quercus* (15–20%), *Salix* (2–20%), Poaceae (20–35%), Asteraceae excluding *Ambrosia* (10–15%) and Cyperaceae (20–25%). Pollen of aquatic plants, especially *Myriophyllum*, was also relatively common. This pollen rain supports the contention that the upland area was an oak savanna and the floodplain supported willows along with other wetland and aquatic plants.

Plant macrofossil analyses of these deposits (Figures 3 and 4) support the idea that a rich mix of aquatic, wetland, wet prairie and riparian elements was present on the floodplain.

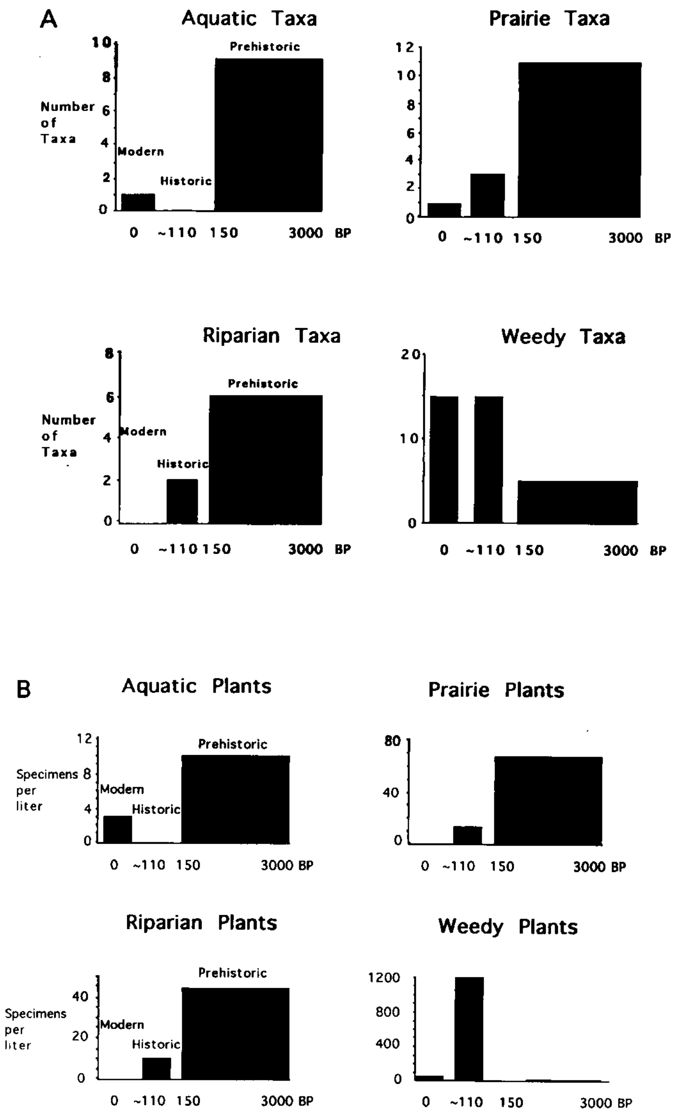

Figure 3 Summary of changes in plant macrofossils arranged in four ecological groups: (1) aquatic, (2) prairie, (3) riparian and (4) ruderal plants. 3A = plotted by number of taxa; 3B = plotted by number of specimens per litre. Prehistoric bar is mean of seven sites (2, 3, 4, 5, 7a, 8 and 9 on Figure 1); historic bar represents one site (6 on Figure 1), and modern bar is mean of two sites (1 and 7 on Figure 1).

The major tree during presettlement time is *Salix*, with single occurrences of *Ulmus americana*, *Tilia americana* and *Quercus*. Forest herbs are restricted to *Ranunculus septentrionalis*, which can grow in riparian forest environments. Shrubs are represented by *Cornus amomum* subspecies *obliqua*, *Cornus* sp. and *Rubus*, all floodplain or edge species. Disturbed ground plants are sparingly present, but most cannot be identified to species. These include *Amaranthus*, *Chenopodium* and *Oxalis*. A variety of prairie indicator species occurs in presettlement sites; among the more regularly occurring are *Amorpha canescens*, *Hypoxis hirsuta*, *Monarda fistulosa*, *Pycnanthemum virginianum*, *Ratibida pinnata*, *Rudbeckia hirta* and *Zizia aurea*. Nine species of aquatic plants also grew in the stream or in floodplain ponds, but their occurrence is sporadic.

Macrofossils of the historical period (Figure 3) were found in site 6 (Figure 1). This site is dated by a piece of barbed wire, which was of the type called 'Glidden's Barb, One-strand Variation' (written communication from A.L. Fisk to D.P. Schwert, 12 August 1989). The patent for this make was issued in 1874, and the site is estimated to date from about 1880.

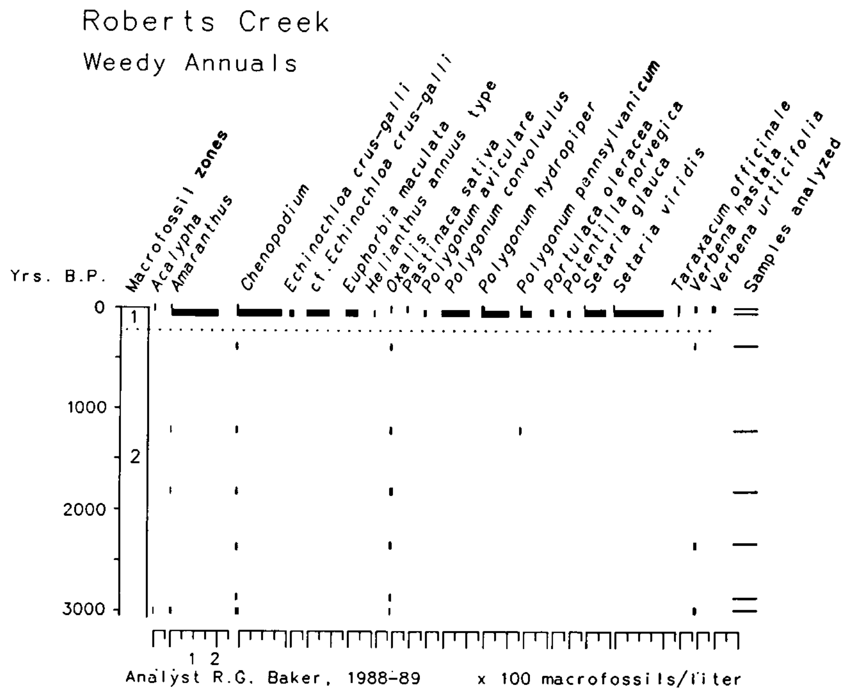

Figure 4 Plant macrofossil diagram of ruderal taxa at Roberts Creek during the last 3000 BP, showing the increase in abundance of most taxa following settlement.

Pollen percentages of *Ambrosia* and Poaceae rise sharply in the historical sample to about 25% and 40% respectively, whereas those of *Quercus*, total arboreal pollen, Asteraceae and Cyperaceae decline to 10%, 20%, <5% and <5% respectively. The rise in *Ambrosia* and the decline in *Quercus* and other trees are widespread in the eastern and midwestern United States and represent land clearance, but effects on other taxa were not known.

The diversity and abundance of plant macrofossils of prairie, aquatic and wetland taxa decreased after settlement occurred (Figures 3 and 4). The number both of taxa and of specimens of aquatic plants decreased from prehistoric (mean of seven samples dated between 3000 BP and ~150 BP) to historic time (one sample from ~AD 1880) and apparently recovered slightly in modern time (two samples). Only *Potamogeton* has been seen in the modern stream, though *Chara* oospores are present in the modern samples. Prairie and riparian taxa and specimens decrease markedly between prehistoric and historic time, and the decrease continues to the modern samples. Only rare *Salix* trees are present along the modern stream, and prairie elements are completely absent from cultivated areas, and rare to absent in pastures on the floodplain. Ruderal annual plants are present in low numbers and diversity prior to settlement, but their diversity triples by ~AD 1880, and the number of specimens increases by about two orders of magnitude. The diversity remains high in the modern samples, but the number of specimens drops to about twice presettlement values.

These 'weeds' included the introduced species, *Pastinaca sativa*, *Polygonum aviculare*, *Polygonum hydropiper*, *Polygonum convolvulus*, *Setaria glauca*, *Setaria viridis* and *Taraxacum officinale*. Native ruderal genera present in small numbers earlier in the Holocene are *Chenopodium*, *Echinochloa* and *Amaranthus* sp. *Euphorbia maculata* appeared only in historical sediment, and *Polygonum pensylvanicum* occurred sparsely in mid-Holocene time, and increased following cultivation.

The plant record indicates that major changes in vegetation occurred following forest clearance and cultivation. The details of the timing of these changes have yet to be established, but by ~AD 1880 most of the changes had occurred. In the uplands, oaks in the savanna apparently had been reduced substantially, and prairies had largely been ploughed under. On the floodplain, native wetland, riparian and prairie communities had been almost completely replaced by crops. Ruderal elements were dominant in the fossil assemblage. By modern time, the prairie and riparian communities had further declined, and aquatic communities in the stream had showed little recovery. Ruderal annuals were considerably less abundant (though diversity remained high).

The correlation of a maximum in ruderal plants with the time of maximum flooding is probably not coincidental. The most abundant niche along the stream for disturbed ground plants would be the bare soil exposed by both erosion and deposition during floods. Ruderal species were at their maximum during this time. The decrease in numbers of ruderal species in modern samples may be explained by: (1) the greater stability and lesser flooding that accompanied enlargement of the meander belt, decreasing the area available for colonization by these plants, and; (2) the use of herbicides in the area in recent decades.

Insects

Twenty one families of beetles are represented in the pre- and post-settlement assemblages (Schwert, in prep.). In addition to beetles, the remains of molluscs, ostracods, spiders, orbatid mites, and other orders of insects are present.

Pre-settlement species

Samples from the presettlement sites contain remarkably diverse assemblages of ground beetles (Carabidae). Most of the species represented are associated with water-marginal or marshland environments. Several, however, including *Cyclotrachelus s. sodalis* LeC., *C. seximpressus* LeC., *Poecilus lucublandus* (Say), and *Amara angustata* (Say), are inhabitants of open grasslands (Lindroth, 1966; 1968; Freitag, 1969). Others, including *Scaphinotus elevatus* (Fab.) and *Pterostichus stygicus* (Say), are woodland species (Lindroth, 1961; 1966). Additional upland taxa include *Hyperaspis brunnescens* Dobz., an apparently rare ladybird (Coccinellidae) species known today only from Iowa and Illinois (Gordon, 1985), and numerous remains of the scarabaeid provisionally identified as *Macrodactylus subspinosus* (Fab.), the common 'rose chafer'.

Dryopoid beetles, particularly elmids, are the numerically largest faunal component of the presettlement assemblages, representing approximately two-thirds of all beetle remains. Five species of elmids (*Dubiraphia* cf. *vittata* [Melsh.], *Macronychus glabratus* Say, *Microcylloepus pusillus* [LeC.], *Optioservus fastiditus* [LeC.] and *Stenelmis* cf. *crenata* [Say]) and one species of dryopid (*Helichus striatus* LeC.) are represented. Dryopoid faunas of this diversity and richness exist today only in association with the bedrock- or gravel-bedded riffle zones of streams of exceptionally high water quality (Brown, 1976; Hilsenoff, 1977).

Numerous water-marginal and marsh-associated taxa are present in the remaining component of the presettlement beetle assemblages. Saprophagous species, however, are poorly represented; the occurrences of the dung-associated scarabaeid *Onthophagus hecate* (Panz.) might have been in association with occasional visits to the stream by large herbivores such as bison.

Together, the insect assemblages show that a mixture of open grasslands and riparian woodlands characterized the drainage basin of presettlement Roberts Creek. The stream itself was of trout-stream water quality, with gravel substrate and with alternating riffles and pools bordered by muddy banks and zones of marsh-associated plants.

Postsettlement species

Of the 12 species of carabids collectively represented in the postsettlement samples, all but one (*Cyclotrachelus sodalis*) are associated with marsh or water-marginal habitats. No woodland-associated carabids are present, although two generalist taxa of bark beetles (Scolytidae) occur.

Upland elements of the postsettlement assemblages are dominated instead by scarabaeids (Scarabaeidae) and weevils (Curculionidae). Of the six species of the scarabaeid dung beetle *Aphodius* definitively or provisionally identified, all are today regularly associated with cattle dung. Two, *A distinctus* (Müller) and *A. granarius* (L.), represent introductions from Europe (Table 2), the latter apparently during the seventeenth century aboard ships carrying cattle from England (Sailer, 1983; Ratcliffe, 1991).

At least six species of the large postsettlement weevil assemblage represent immigrant species that themselves are associated with immigrant host plants (Table 2). Nearctic weevil species (and their associated host plants) include *Hypera* cf. *compta* Say (*Polygonum coccineum*), *Nedyus flavicaudis* (Boh.) (*Urtica* sp.), *Listronotus* cf. *appendiculatus* (Boh.) (*Sagittaria* spp.), and the billbug weevils *Sphenophorus parvulus* Gyll. and *S. minimus* Hart. (serious pests of turf-forming grasses) (Puttler *et al.*, 1973; Vaurie, 1983; Johnson-Cicalese *et al.*, 1990; R.S. Anderson, pers. comm., 1990).

Other anthrophilic taxa represented in the postsettlement assemblages include the palaearctic chrysomelid *Phyllotreta striolata* (Fab.) (a widespread pest, particularly of cruciferous vegetables) and the nearctic nitidulid *Glischrochilus quadrisignatus* Say (a pest of fruit and maize) (Smith, 1985; Bousquet, 1990). Fossils of the cryptophagid *Atomaria ephippiata* Zimm. and a cucujid provisionally identified as *Cryptolestes ferrugineus* (Steph.) are present; these species commonly occur today in association with stored grains, the latter being a serious pest, particularly of wheat (Bousquet, 1990).

Whereas the remains of dryopoid water beetles overwhelmingly dominated the presettlement assemblages, they are nearly absent from postsettlement samples (Figure 5). Replacing elmids as the most abundant water beetle taxon is the haliplid *Peltodytes edentulus* LeC., one of the few species of aquatic beetles that appears to thrive in shallow, eutrophic and polluted pools and streams.

Interpretation of the insect evidence

Records compiled from museum and literature sources indicate that all of the beetle species identified from pre- and postsettlement samples could potentially occur within the region of Roberts Creek today. The postsettlement transformation of the landscape by cultivation appears to have profoundly affected the species diversity of the carabid and scarabaeid faunas (Figure 6). In this analysis, the pre- and postsettlement representations of these families are standardized to species per kilogram of sample sediment. Carabid diversity markedly decreases, with upland species in particular being no longer well represented in postsettlement

Table 2 Exotic species of Coleoptera represented as fossils in samples of postsettlement age from the Roberts Creek basin, with notes on their habitats, host plants, or food sources

Taxa	Habitat or host plant	References
Staphylinidae:		
Platystethus degener Muls. and Rey	Dung of large, herbivorous mammals although beetle is probably predaceous	Moore and Legner, 1971; Moore, 1979
Scarabaeidae:		
Aphodius granarius L.	Dung of large, herbivorous mammals	Ratcliffe, 1991
Aphodius distinctus (Müller)	Dung of large, herbivorous mammals	Ratcliffe, 1991
Chrysomelidae:		
Phyllotreta striolata (Fab.)	Pest of cruciferous vegetables*	Smith, 1985
Curculionidae:		
Calomycterus setarius Roelofs	*Medicago sativa** (alfalfa) and *Trifolium pratense** (red clover)	J.P. Johnson, 1944
Sitona cf. *hispidulus* (Fab.)	Pest of *Medicago sativa** (alfalfa) and *Trifolium* spp.* (clover)	Blatchley and Leng, 1916; Godfrey and Yeargan, 1989
Hypera punctata (Fab.)	Pest of *Trifolium pratense** (red clover)	Litsinger and Apple, 1984
Gymnetron netum (Germar)	*Linaria vulgaris** (butter-and-eggs)	Hoffman, 1954
Ceutorhynchus erysimi (Fab.)	Pest of cruciferous vegetables	Harde, 1981
Ceutorhynchus punctiger Gyll.	*Taraxacum officinale** (dandelion)	McAvoy *et al.*, 1983

Note: *Host plants of palearctic origin (Gleason and Cronquist, 1963).

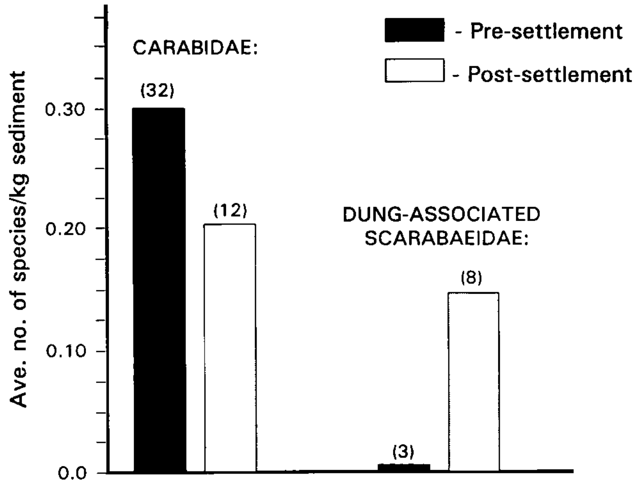

Figure 5 Changes in average numbers of carabid and dung-associated scarabaeid species represented per kilogram of sediment in pre- and postsettlement deposits of Roberts Creek.

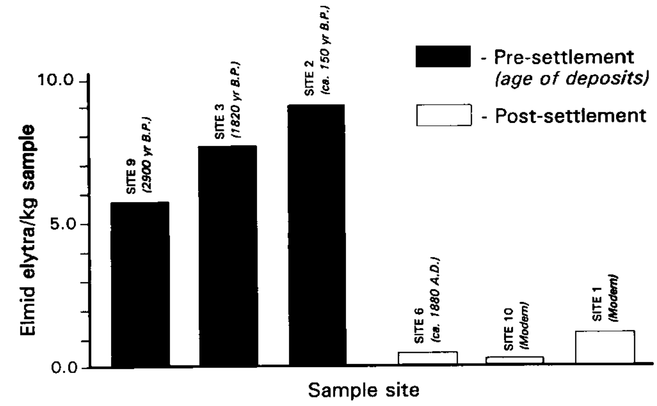

Figure 6 Changes in total numbers of elmid elytra represented per kilogram of sediment in pre- and postsettlement deposits of Roberts Creek. Age of deposits is given in italics.

samples; the detrimental impact on carabid populations by agricultural manipulation of modern landscapes has been well documented (e.g., Luff and Rushton, 1989; Weiss *et al.*, 1990). The diversity of dung-associated scarabaeids, however, sharply increases upon settlement, as cattle and other large herbivores are introduced to graze proximal to Roberts Creek.

Sedimentation and eutrophication associated with agricultural transformation of the landscape likewise made the waters of Roberts Creek inhospitable to most species of aquatic Coleoptera. Although we commonly encountered live elmids in abundance clinging to stones in riffle areas of the nearby Turkey River, dryopoid beetles today rarely occur in the waters of Roberts Creek (Kennedy and Miller, 1990). A thick layer of sediment of postsettlement age now blankets what was once the gravel or bedrock bottom of Roberts Creek, effectively eliminating drypoid habitat. As might be predicted, water-marginal beetles, inhabiting zones that are directly affected by neither cultivation nor eutrophication, represent the group least affected by Euro-American settlement.

The faunal record of changes marking the transformation of the Roberts Creek basin to an agricultural landscape bear remarkable similarities to fossil insect records of the English Midlands as observed by Osborne (1974; 1988). Forests that had once characterized the region proximal to the River Avon in Warwickshire were by late Bronze Age (*ca.* 2900 BP) largely replaced by grasslands occupied by large grazing herbivores such as cattle and sheep. As forest clearing and ploughing of the landscape progressed, soil erosion led to increased sedimentation and to the elimination of the rich elmid populations of the River Avon.

Conclusions

The spread of agriculture in northeastern Iowa had several impacts on the local ecosystem and landscape in the time following settlement.

(1) During the land clearance phase, stable vegetation types were replaced by disturbed ground plants, and soils were degraded by cultivation and poor conservation practices. This disturbance apparently was at its peak between ~AD 1880 and 1930.

(2) The loss of stable vegetation cover and infiltration capacity caused by soil erosion resulted in increased runoff, thereby increasing flood frequency and magnitude for several decades after land clearance.

(3) These changes greatly accelerated hill slope erosion, removing the A horizons of upland soils and depleting their tilth and fertility.

(4) Increased sediment delivery to the valley network resulted in the accumulation of up to 2 m of sediment derived from uplands and slopes in the channel belt and between 0.4 and 1.0 m on the floodplain between ~AD 1890 and 1920. This new alluvium was fertile, but the rapid sedimentation rate (approximately 5–25 times the presettlement rate) across much of the valley floor resulted in edaphic conditions that favoured colonization by disturbed ground plants.

(5) Since ~AD 1920, channel widening has decreased flooding and floodplain aggradation rates.

(6) Diversity of native plants has decreased, and native plant communities have been lost to aggressive introduced species that are temporary colonizers of disturbed ground.

(7) Water quality has been severely degraded from a clear, cold-water trout stream to a polluted, silt-laden creek.

(8) Changes in beetle populations show that upland carabids declined and taxa associated with crop plants and cattle dung increased.

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References

Ashworth, A.C. 1979: A method of recovering fossil insect remains from clays, peats, and silts. In Erwin, T.L., Ball, G.E. and Whitehead, D.R. editors, *Carabid beetles, their evolution, natural history, and classification*, The Hague: W. Junk, 406.

Benton, T.H. and **Gray, A.L.** 1925: *Soil survey of Clayton County, Iowa*. Washington, D.C.: U.S. Dept. of Agriculture, Bureau of Chemistry and Soils.

Bettis III, E.A. 1984: Preliminary investigations of the stratigraphy and chronology of northeastern Iowa alluvium and its archaeological significance with special reference to the Turkey River Basin. Report submitted to the Iowa State Historical Department, Division of Historic Preservation, Des Moines.

—— 1990: Holocene Alluvial Stratigraphy and Selected Aspects of the Quaternary History of Western Iowa. *Guidebook for the 37th Midwest Friends of the Pleistocene Field Conference*.

Bettis III, E.A. and **Littke, J.P.** 1987: Holocene alluvial stratigraphy and landscape development in Soap Creek Watershed Appanoose, Davis, Monroe, and Wapello counties, Iowa. *Iowa Department of Natural Resources, Geological Survey Bureau. Open File Report* 87-2. Iowa City.

Birks, H.H., Birks, H.J.B., Kaland, P.E. and **Moe, D.** 1988: *The cultural landscape – past, present and future*. Cambridge: Cambridge University Press.

Birks, H.H., Whiteside, M.C., Stark, D.M. and **Bright, R.C.** 1976: Recent paleolimnology of three lakes in northwestern Minnesota. *Quaternary Research* 6, 249–72.

Blatchley, W.S. and **Leng, C.W.** 1916: *Rhynchophora or weevils of north eastern America*. Indianapolis: Nature Publications.

Bousquet ,Y. 1990: *Beetles associated with stored products in Canada: an identification guide*. Ottawa, Canada: Agriculture Canada Research Branch Publication 1837.

Bradbury, J.P. and **Waddington, J.C.B.** 1973: The impact of European settlement on Shagawa Lake, northeastern Minnesota, U.S.A. In Birks, H.J.B. and West, R.G., editors, *Quaternary Plant Ecology*, Oxford: Blackwell, 289–317.

Brown, H.P. 1976: Aquatic dryopoid beetles (Coleoptera) of the United States. Cincinnati, Ohio, USA: *US Environmental Protection Agency Water Pollution Control Research Series* 18050-ELD04/72.

Brugham, R.B. 1978: Human disturbance and the historical development of Linsley Pond. *Ecology* 59, 19–36.

Buckland, P.C. and **Kenward, H.K.** 1973: Thorne Moor: a palaeo-ecological study of a Bronze Age site. *Nature* 241, 405–406.

Chumbley, C.A. 1988: Late glacial and Holocene vegetation. In Green, W., editor, *Archaeological and paleoenvironmental studies in the Turkey River Valley, northeastern Iowa*, Report to the Iowa State Preserves Board, 74–109.

—— 1989: Late-glacial and Holocene vegetation of the Roberts Creek Basin, northeast Iowa. University of Iowa Ph.D. Dissertation, 154 pp.

Chumbley, C.A., Baker, R.G. and **Bettis III, E.A.** 1990: Midwestern Holocene paleoenvironments revealed by floodplain deposits in northeastern Iowa. *Science* 249, 272–74.

Cwynar, L.C., Burden, E. and **McAndrews, J.H.** 1979: An inexpensive method for concentrating pollen and spores from fine grained sediments. *Canadian Journal of Earth Sciences* 16, 1115–20.

Davis, M.B. 1973: Pollen evidence of changing land use around the shores of Lake Washington. *Northwest Science* 47, 133–48.

—— 1989: Retrospective studies. In Likens, G.E., editor, *Long-term studies in ecology, approaches and alternatives*, New York: Springer-Verlag, 71–89.

Delcourt, P.A., Delcourt, H.R., Cridlebaugh, P.A. and **Chapman, J.** 1986: Holocene ethnobotanical and paleoecological record of human impact on vegetation in the Little Tennessee River Valley, Tennessee. *Quaternary Research* 25, 330–49.

Dick, W. and **Tabatabai, M.A.** 1977: An alkaline oxidation method for the determination of total phosphorous in soils. *Soil Science Society of America Proceedings* 41, 511–14.

Elias, S.A. 1986: Fossil insect evidence for late Pleistocene paleo-environments of the Lamb Spring site, Colorado. *Geoarchaeology* 1, 381–87.

—— 1990: The timing and intensity of environmental changes during the Paleoindian period in western North America: evidence from the insect fossil record: In Agenbroad, L., Mead, J. and Nelson, L., editors, *Megafauna and man*, Flagstaff: Northern Arizona University Press, 11–14.

Faegri, K., Kaland, P.E. and **Krzywinski, K.** 1989: *Textbook of Pollen Analysis*. New York: John Wiley and Sons.

Freitag, R. 1969: A revision of the species of the genus *Evarthrus* LeConte (Coleoptera: Carabidae). *Quaestiones Entomologicae* 5, 89–212.

General Land Office Survey of Wisconsin Territory 1837–1849.

Gleason, H.A. and **Cronquist, A.** 1963: *Manual of vascular plants of northeastern United States and adjacent Canada*. New York: D. Van Nostrand.

Godfrey, L.D. and **Yeargan, K.V.** 1989: Effects of clover root curculio, alfalfa weevil (Coleoptera: Curculionidae), and soil-borne fungi on alfalfa stand density and longevity in Kentucky. *Journal of Economic Entomology* 82, 1749–56.

Gordon, R.D. 1985: The Coccinellidae (Coleoptera) of America north of Mexico. *Journal of the New York Entomological Society* 93, 1–912.

Harde, K.W. 1981: *A field guide in colour to beetles*. London: Octopus Books.

Hisenoff, W.L. 1977: Use of arthropods to evaluate water quality of streams. Wisconsin Department of Natural Resources (Madison) Technical Bulletin No. 100, 15 pp.

Hoffman, A. 1954: *Faune de France. 59. Coléoptères curculiondes (Deuxieme Partie)*. Paris: Federation Francaise des Sociétés de Sciences Naturelles.

Iowa State Census 1856.

James, L.A. 1991: Incision and morphologic evolution of an alluvial channel recovering from hydraulic mining sediment. *Geological Society of America Bulletin* 103, 723–36.

Johnson, J.P. 1944: The imported long-horned weevil *Calymycterus setarius* Roelofs. *Bulletin of the Connecticut Agricultural Experiment Station* 19, 121–42.

Johnson, W.C., editor, 1987: *Quaternary environments of Kansas. Kansas Geological Survey, Guidebook Series 5*, Lawrence.

Johnson-Cicalese, J.M., Wolfe, G.W. and **Funk, C.R.** 1990: Biology, distribution, and taxonomy of billbug turf pests (Coleoptera: Curculionidae). *Environmental Entomology* 19, 1037–46.

Kennedy, J.O. and **Miller III, J.G.** 1990: A survey of the benthic macroinvertebrates of the Big Spring Basin, Iowa. *Journal of the Iowa Academy of Sciences* 97, 46–54.

Kenward, H.K. 1976: Reconstructing ancient ecological conditions from insect remains; some problems and an experimental approach. *Ecological Entomology* 1, 7–17.

Knox, J.C. 1987: Historical valley floor sedimentation in the Upper Mississippi Valley. *Annals of the Association of American Geographers* 77, 224–44.

Lindroth, C.H. 1957: *The faunal connections between Europe and North America*. New York: John Wiley and Sons.

—— 1961: The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska (2). *Opuscula Entomologica Supplementum* 20, 1–200.

—— 1966: The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska (4). *Opuscula Entomologica Supplementum* 29, 409–648.

—— 1968: The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska (5). *Opuscula Entomologica Supplementum* 33, 649–944.

Litsinger, J.A. and **Apple, J.W.** 1984: Summer diapause of the clover leaf weevil, *Hypera punctata* and lesser clover leaf weevil, *Hypera nigrirostris*, in Wisconsin. *Great Lakes Entomologist* 17, 83–86.

Luff, M.L. and **Rushton, S.P.** 1989: The ground beetle and spider fauna of managed and unimproved upland pasture. *Agriculture Ecosystems and Environments* 25, 195–205.

Magilligan, F.J. 1985: Historical floodplain sedimentation in the Galena River basin, Wisconsin and Illinois. *Annals of the Association of American Geographers* 75, 583–94.

Maher, L.J., Jr. 1977: Palynological studies in the western arm of Lake Superior. *Quaternary Research* 7, 14–44.

McAndrews, J.H. 1988: Human disturbance of North American forests and grasslands: The fossil pollen record. In Huntley, B. and Webb III, T., editors, *Vegetation history*, Dortdrecht: Kluwer, 673–97.

McAvoy, T.J., Kok, L.T. and **Trimble, J.T.** 1983: Biological studies of *Ceutorhynchus punctiger* (Coleoptera: Curculionidae) on dandelion in Virginia. *Annals of the Entomological Society of America* 76, 671–74.

McLeod, J.M. 1980: Forests, disturbances, and insects. *The Canadian Entomologist* 112, 1185–92.

Moore, I. 1979: *Platystethus cornutus* Gravenhorst reported from the United States is *P. degener* Mulsant and Rey (Coleoptera: Staphylinidae). *Coleopterists Bulletin* 33, 32.

Moore, I. and **Legner, E.F.** 1971: A review of the nearctic species of *Platystethus* (Coleoptera: Staphylinidae). *Pan-Pacific Entomologist* 47, 260–64.

Osborne, P.J. 1974: An insect assemblage of early Flandrian age from Lea Marston, Warwickshire, and its bearing on the contemporary climate and ecology. *Quaternary Research* 4, 471–86.

—— 1988: A late Bronze Age insect fauna from the River Avon, Warwickshire, England: its implications for the terrestrial and fluvial environment and for climate. *Journal of Archaeological Science* 15, 715–27.

Puttler, B., Thewke, S.E. and **Warner, R.E.** 1973: Bionomics of three nearctic species, one new, of *Hypera* (Coleoptera: Curculionidae), and their parasites. *Annals of the Entomological Society of America* 66, 1299–1306.

Ratcliffe, B.C. 1991: The scarab beetles of Nebraska. *Bulletin Nebraska State Museum* 12, 1–333.

Sailer, R.I. 1983: History of insect introductions. In Wilson, C.L. and Graham, C.L., editors, *Exotic plant pest and North American agriculture*, New York: Academic Press, 15–38.

Sartz, R.S. 1975: Controlling runoff in the Driftless Area. *Journal of Soil and Water Conservation* 30, 92–93.

—— 1976: Sediment yield from steep lands in the Driftless Area. In *Proceedings of the Third Federal Inter-Agency Sedimentation Conference*, Washington, D.C.: U.S. Government Printing Office, I-123–31.

Smith, E.H. 1985: Revision of the genus *Phyllotera* Chevrolat of America north of Mexico. Part I. The maculate species (Coleoptera: Chrysomelidae, Alticinae). *Fieldiana (Zoology, New Series)* 28, 1–168.

Soil Survey Staff 1975: *Soil Taxonomy*. Washington, D.C.: U.S. Department of Agriculture Handbook 436.

Tsukada, M. 1972: The history of Lake Nojiri, Japan. *Connecticut Academy of Arts and Sciences Transactions* 44, 339–65.

Turnbull, A.L. 1980: Man and insects: the influence of human settlement on the insect fauna of Canada. *The Canadian Entomologist* 112, 1177–84.

Vaurie, P. 1983: *A catalog of the Coleoptera of America north of Mexico. Family: Curculionidae. Subfamily: Rhynchophorinae*. Washington, D.C.: U.S. Department of Agriculture Handbook 529–143a.

Walter, N.F., Hallberg, G.R. and **Fenton, T.E.** 1978: Particle-size analysis by the Iowa State University Soil Survey Laboratory. In Hallberg, G.R., editor, *Standard Procedures for Evaluation of Quaternary Materials in Iowa*, Iowa City: Iowa Geological Survey, Technical Information Series No. 8, 61–74.

Webb III, T., Cushing, E.J. and **Wright, H.E., Jr.** 1983: Holocene changes in vegetation of the Midwest. In Wright, H.E., Jr., editor, *Late Quaternary environments of the United States, Volume 2, The Holocene*, Minneapolis: University of Minnesota Press, 142–65.

Weiss, M.J., Balsbaugh, E.U., Jr., French, E.W. and **Hoag, B.K.** 1990: Influence of tillage management and cropping system on ground beetle (Coleoptera: Carabidae) fauna in the northern Great Plains. *Environmental Entomology* 19, 1388–91.

Yeomans, J.C. and **Bremner, J.C.** 1991: Carbon and nitrogen analysis of soils by automated combustion techniques. *Communications in Soil Science and Plant Analysis* 22, 843–850.