The Fluvial and Geomorphic Context of Indian Knoll, an Archaic Shell Midden in West-Central Kentucky

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Indian Knoll is the largest Archaic shell midden excavated by WPA archaeologists in Kentucky. Situated in a large alluvial valley, the site is not associated with a known river shoal as might be expected, making its fluvial and geomorphic setting of interest. Based on sediment cores and auger samples, undisturbed portions of the site remain despite extensive excavations. In undisturbed portions, a shell-bearing layer is overlain by a shell-free midden layer. Profiles of organic matter and calcium carbonate content for both layers are similar to those of other Green River shell middens. New radiocarbon determinations date the shell deposit at 5590–4530 cal yr B.P. Analysis of mussel species collected from the Indian Knoll indicates that shell fishing took place in a swiftly flowing, shallow to moderately deep setting of the main river channel. Overall, the prehistoric river setting adjacent to Indian Knoll was characterized by deeper water on average with variable but finer-grained substrate compared to other Green River shell midden sites. © 2002 Wiley Periodicals, Inc.

INTRODUCTION

Indian Knoll (15Oh2) holds a special place in the history of North American archaeology. The most famous of numerous late Middle and Late Archaic period (ca. 6000–3000 yr B.P.) shell middens along the Green River in Kentucky (Figure 1; see also Hensley, 1991:78), it first attracted the attention of the archaeological explorer C.B. Moore, who in 1915 removed 298 burials and associated artifacts (Moore, 1916). Later, under the auspices of the Works Progress Administration (WPA), William Webb supervised extensive excavations at several Green River sites during the late 1930s and early 1940s (see Schwartz, 1967; Jefferies, 1988a; Lyon, 1996; Crothers, 1999:15–33). Webb's crews removed another 880 human burials along with 55,000 artifacts from Indian Knoll, and in so doing, excavated most of

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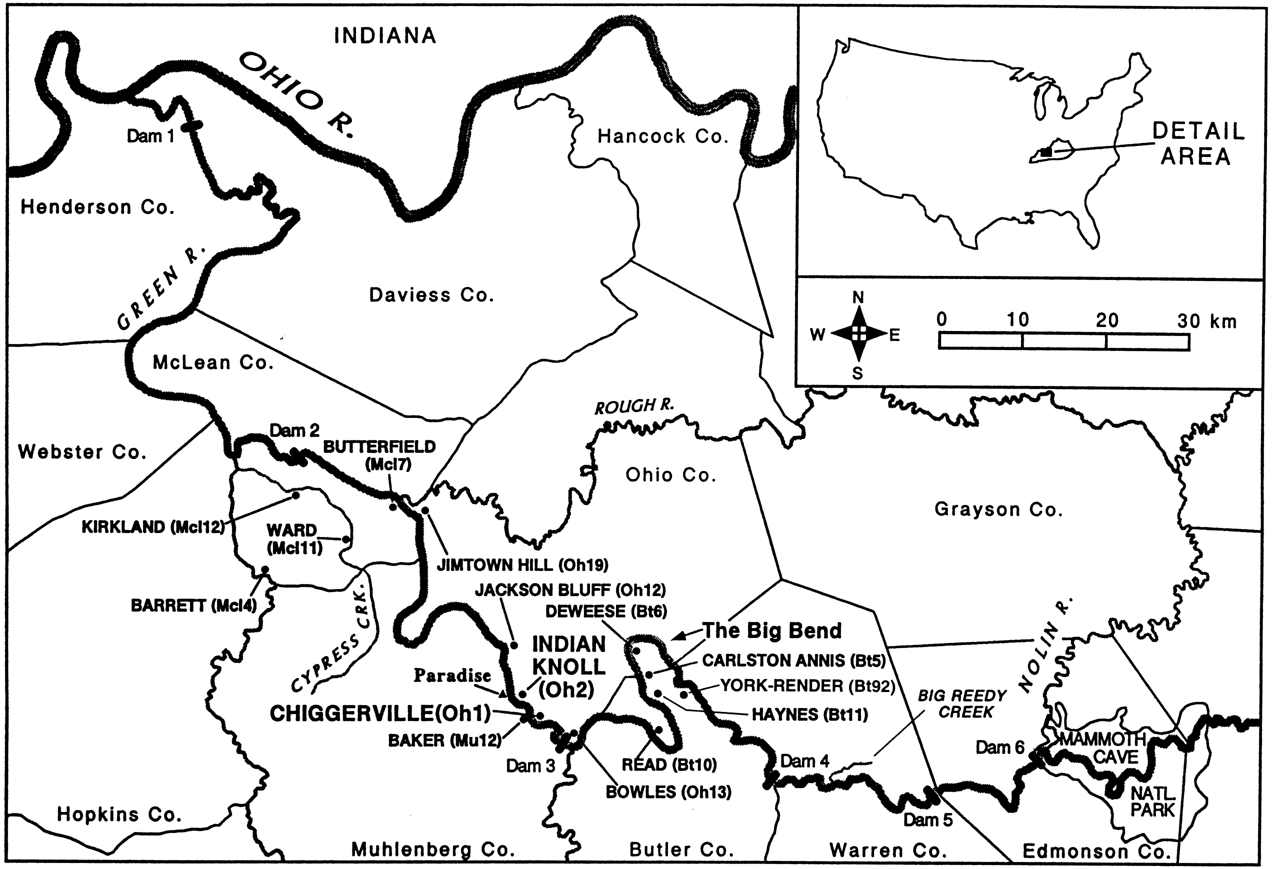

Figure 1. Map of the Green River Valley in western Kentucky, showing the location of Indian Knoll, Chiggerville, and other major Archaic Period sites, along with dams and other locations mentioned in the text (adapted from Marquardt and Watson [1983a:325]).

the site. Webb's monograph on Indian Knoll (Webb, 1946), republished in 1974 (Webb, 1974), is the longest report stemming from the WPA work along the Green River (e.g., Webb and Haag, 1939, 1940, 1947; Webb, 1950a, 1950b) and stands as a classic in the literature of North American archaeology.

The importance of Indian Knoll, however, lies not in its history of professional work *per se*, but in how that history shapes our understanding of eastern Archaic period lifeways in general (Winters, 1974:vii) and the Green River Archaic in particular. The WPA work along the Green River, with Indian Knoll as the "signature" site, was a key component in establishing and refining the very concept of an Archaic period in eastern North America (see Jefferies, 1988a, 1988b; Chapman and Watson, 1993). The human skeletal remains from Indian Knoll are the most widely used Archaic period sample for bioarchaeological studies in eastern North America (Haskins and Herrmann, 1996; Powell, 1996; Smith, 1996:135); thus, these people are the foundation for our understanding of health and nutrition in Archaic times. At a regional level, Rolingson's (1967) analysis of WPA collections led her to recognize an Indian Knoll focus, while Winters (1968, 1969, 1974) used WPA data to model the settlement-subsistence system of Green River Archaic people, freely referring to them collectively as the "Indian Knoll culture."

As Winters (1974) recognized, however, we still know relatively little about the people of Indian Knoll and other Green River Archaic sites; and, as Fenton et al. (1997) have suggested, despite real progress since Winters was writing, it would be fair to say that we still have more debatable issues than hard facts. On the one hand, we can credibly describe these people as fisher-gatherer-hunters with complex political, ecological, and economic strategies but with minimal social ranking and little investment in horticulture (see Marquardt, 1985; Watson, 1985; Marquardt and Watson, 1997; Crothers, 1999). Much is known about their mortuary customs, skeletal biology, basic lithic and bone-working industries, and the scale and material content of the major midden accumulations they left behind. On the other hand, we are much less sure why major sites are positioned as they are on the landscape, how different sites were used in relation to each other, or how they articulate with a larger seasonal round of economic and social activities (Hensley, 1994; Watson, 1996; Morey and Crothers, 1998; Crothers, 1999).

Not surprisingly, there is clear recognition that considerably more empirical data from the Green River valley are needed (Winters, 1974; Claassen, 1996a; Watson, 1996; Marquardt and Watson, 1997; Morey and Crothers 1998) and that examination of the WPA-era collections and records is an essential part of this endeavor (e.g., Rolingson, 1967; Hensley, 1994; Claassen, 1996b; Fenton et al., 1997; Milner and Jefferies, 1998). Although the WPA work followed a high standard for its day, that standard did not include modern approaches to geoarchaeological investigation or the systematic recovery of organic remains. Thus, an equally essential task is the generation of new field data, a challenge taken up beginning in the early 1970s by William Marquardt and Patty Jo Watson, who initiated the Shell Mound Archaeological Project, or SMAP (Stein, 1980, 1982; Marquardt and Watson, 1983a, 1983b), an effort that focused on the Carlston Annis site, 15Bt5 (Webb, 1950a). Christine

Hensley and George Crothers then continued the SMAP tradition in the late 1980s and 1990s with test excavations at the nearby York-Render (15Bt92), Haynes (15Bt11), and DeWeese (15Bt6) middens (see Figure 1), sites not excavated by WPA crews (Hensley, 1994; Crothers, 1999). At about the same time Crothers was completing his work, James Fenton and colleagues were independently initiating efforts to revisit Indian Knoll (Fenton et al., 1999).

Renewed field investigations in this region underscore the difficulties in understanding the overall significance of the major shell midden sites and resolving why they were located, and hence distributed over time, as they were. It was probably inevitable that independent researchers, puzzling over such issues, would eventually converge at the perceived nexus of the cultural system in question: Indian Knoll. Below, we describe preliminary results of exploratory operations at Indian Knoll (Fenton et al., 1999; Herrmann and Fenton, 2000), with emphasis on geoarchaeological and zooarchaeological data concerning the position of this site on the landscape.

The initial frame of reference for this presentation is a simple tactical proposition: River shoals supporting mussel beds and other subsistence resources were resource-rich zones to which Archaic Period hunters and gatherers were drawn and may have periodically served as aggregation points for economic, social, and ritual purposes (e.g., Hofman, 1985, 1986; Claassen 1991, 1992, 1996b; Crothers, 1999). Thus, to the extent that such shoal settings are stable through time, we expect close correspondence between their locations and Archaic period midden accumulations. With this proposition in mind, we begin by briefly describing the geomorphic setting of the Green River valley. We then focus on specific questions about site distributions and placement, with special reference to Indian Knoll. Finally, we present our efforts to answer those questions based on field data and laboratory analysis of material samples generated during several brief excursions to the site and its environs.

THE GEOMORPHIC SETTING

We recognize three major divisions of the Green River system, shown schematically in Figure 2. The lower Green is that portion from the mouth up to approximately Paradise, Kentucky (opposite Indian Knoll); the middle is a shorter stretch from Paradise up to about Big Reedy Creek; and the upper is the remainder of the valley, above Big Reedy Creek. The explanation below is drawn primarily from Stein (1980), with several modifications (see also McFarlan, 1961; Crothers, 1999: 108–117).

The lower Green River flows through Kentucky's Western Coal Field region and is in a deep valley with a broad, flat valley floor. The river is incised into lacustrine deposits that built up during the Pleistocene, when it was intermittently dammed by alluvial deposits of the Ohio River. The thickness of deposits forming this lake plain can exceed 50 m. Deeply cut through the plain of Pleistocene Green Lake, the modern channel is dominated by fine-grained silts and clays, forming steep,

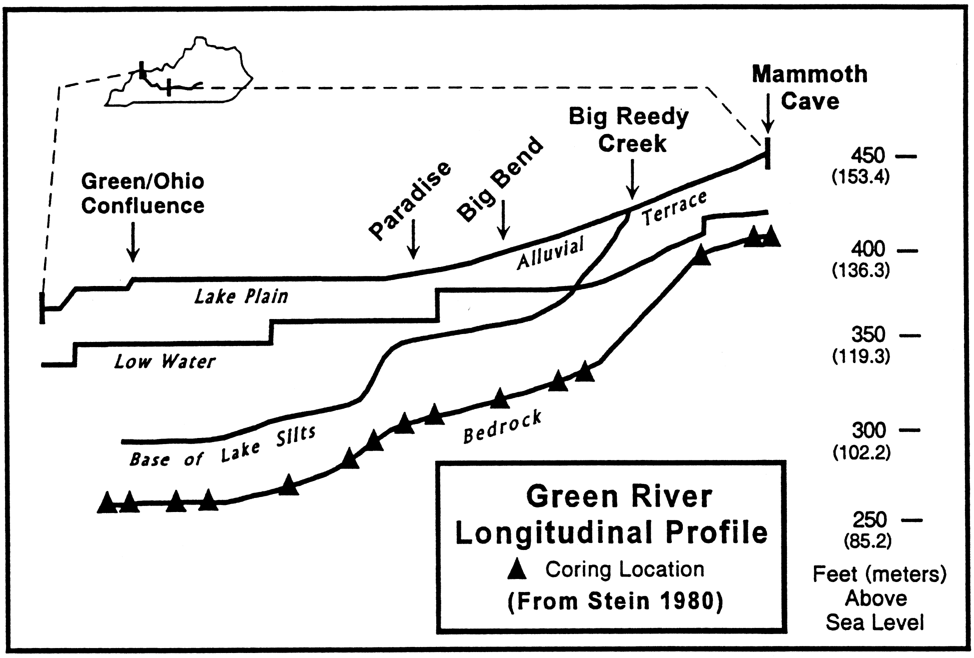

Figure 2. Schematic longitudinal profile of the Green River Valley in Kentucky, including approximate boundary points between the lower (mouth to Paradise), middle (Paradise to Big Reedy Creek), and upper (above Big Reedy Creek) sections.

cohesive banks. Significant shallow areas, including mussel-rich shoals, would be expected only at occasional stable locations where bedrock intersects and thus influences channel shape. The distinction between the lower and middle Green (see below) is gradual rather than abrupt.

At the opposite extreme, the upper Green flows through the Pennyroyal Plateau, a limestone area dominated by karst topography, beyond the ponding effect of Pleistocene Green Lake. The valley is much narrower and more steeply walled, with a channel dominated by sands and gravels, in contrast to the clays and silts of the lower Green. Mussel-bearing shallow stretches are presently common, but significant shell midden sites are not presently recorded in the upper Green. The distinction between the upper and middle Green is relatively well demarcated.

The middle Green, between Paradise and Big Reedy Creek, can be described as a transitional section. The ponding effect of Pleistocene Green Lake extended through this section, but more intermittently, and over a steeper gradient than in the lower valley. Lacustrine deposits begin to thin near Paradise and are no longer detectable at about Big Reedy Creek. This section, and especially the Big Bend (see Figure 1), represents a delta that entered Green Lake during the Pleistocene, and includes traits of both the upper and lower sections. The channel remains wide and is dominated by fine-grained sediments, although probably not as markedly as the lower Green. Some shoals in the middle Green will be bedrock-controlled, but temporary or migrating bars are also a possibility. We cannot presently establish the nature of the ancient shoals that were once associated with Haynes, Carlston Annis, and other sites in the Big Bend, although the taxonomic composition of the shellfish assemblages clearly indicates relatively shallow, swift waters that flowed over sand or gravel-sand substrate (Patch, 1976; Morey and Crothers, 1998). We suggest that these former shoals were bedrock-controlled, and anticipate future geoarchaeological testing to evaluate the effects of bedrock on the channel.

Both the lower and middle sections have been impounded for more than 150 years by a series of four locks and dams, and the U.S. Army Corps of Engineers has periodically dredged parts of the river to maintain adequate depth for commercial traffic (see Morey and Crothers, 1998:909). Consequently, the river is altered from its original state, complicating efforts to identify shoals or other key features today. Our ability to tackle this complication was improved, however, when we located a set of eight maps, 1891 ink tracings of the original 1829 pre-impoundment survey maps, produced to aid planning for the dams (Coppin, 1891; for details see Morey and Crothers, 1998:921–922; Crothers, 1999:141–151). These maps include depth soundings in feet, and depiction of shallow stretches, including shoals that are sometimes named.

In the lower Green, preliminary observations suggest a strong correlation between stable shoals depicted on these maps and known shell midden sites, although little is known about many of the sites in question (Crothers, 1999:144–146; Morey et al., 1999). In the middle Green, the Big Bend sites noted above present greater difficulties for correlating features of the river with site locations; the situation downstream, in the Indian Knoll/Chiggerville area, underscores this challenge. Figure 3 shows two sections of river as depicted in the old survey maps, one adjacent to Indian Knoll, the other ca. 3.5 river miles (5.6 km) upstream, opposite Chiggerville (15Oh1) and the Baker Site (15Mu12). At Chiggerville, a large shoal named Nun's Ripple and at Baker a shoal (next to the word "Coal" and unnamed on this figure but known as Andrew's Run) are depicted in Figure 3(a), a series of two shoals with depths as shallow as 6 in. (15.24 cm). Such a setting is consistent with the presence of a substantial mussel bed, along with two small Archaic shell midden sites associated with it (Webb and Haag, 1939; Crothers et al., 2000; McBride, 2000). The stable shoals appear to be formed where the river crosses the Browder Fault System creating a 7.5 ft (2.29 m) offset at Baker and an 11 ft (3.35 m) offset at Nun's Ripple (Crothers et al., 2000). Mussel species from the midden would reflect the shoal habitat that once existed along this stretch (see Warren, 1991; Morey and Crothers, 1998), but at present no shellfish remains are available for study.

If any place were a good candidate for social aggregation, centered on a resource-rich river shoal, it should be the largest and richest site: 15Oh2, Indian Knoll (Figure 4). Indian Knoll is 150 m northeast of the present channel, however, and the pre-impoundment maps show no features even vaguely suggestive of a nearby shoal.

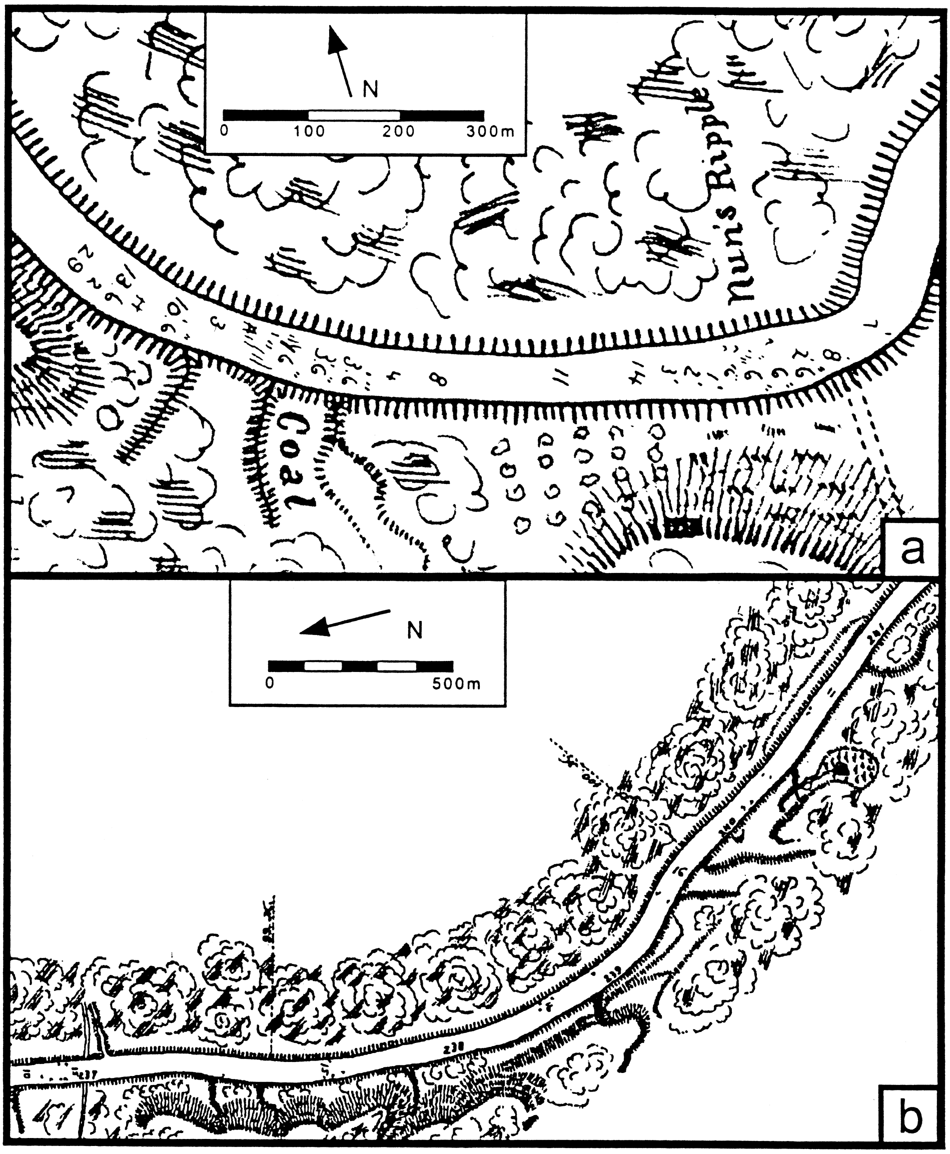

Figure 3. Digitally scanned and filtered images of selected sections of pre-impoundment (1829) Green River survey map no. 6 (Coppin, 1891). (a) Section immediately adjacent to Chiggerville; (b) section flowing past the Indian Knoll area. Information depicted within the channel has been digitally enhanced for clarity.

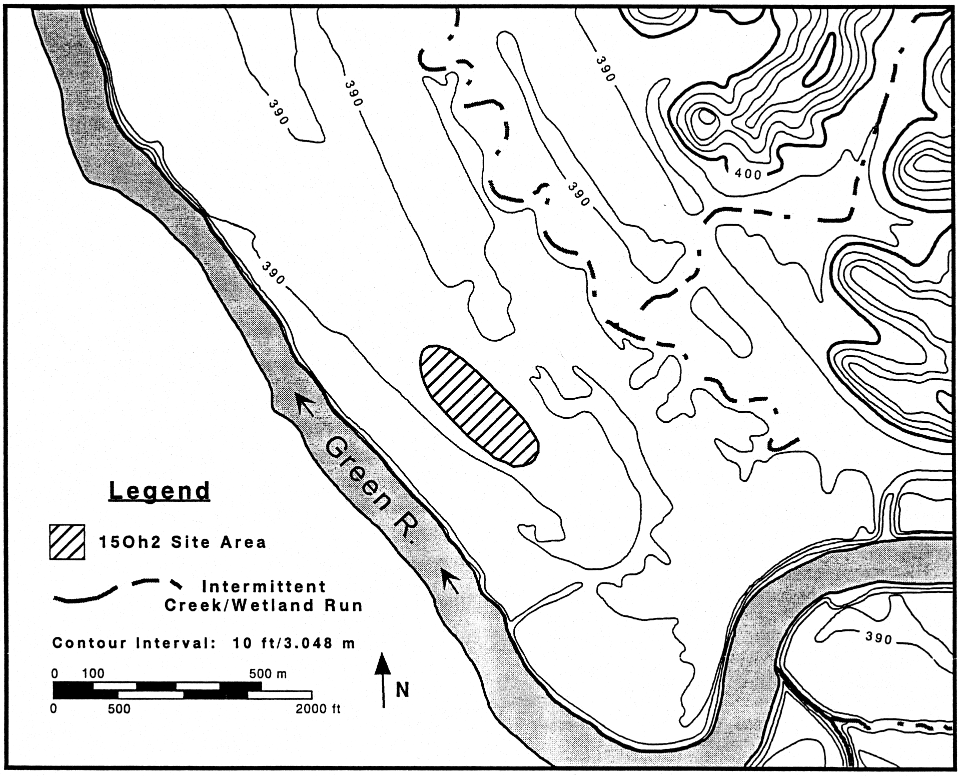

Figure 4. Simplified map of the Indian Knoll site area, showing major topographic features. Given the history of site vandalism in this region, some details have been omitted to avoid revealing the site's precise location.

A depth sounding of 16 feet (4.9 m) is the shallowest in the vicinity, and the nearest recognizable shoal is the one ca. 3.5 river miles (5.6 km) upstream at Chiggerville (Figure 3[b]). In contrast, even in the Big Bend where channel migration subsequent to site occupation had been documented, historically noted shallow areas were present in the general vicinity of the principal midden sites (Morey and Crothers, 1998:922).

Before the opportunity to visit Indian Knoll, we offered several suggestions to account for the site's physiographic circumstances. For example, Webb (1946:119) wrote in his original report that "while the site here is a shell 'mound,' shell is by no means the major constituent in the accumulation." Thus, we speculated that perhaps Indian Knoll was not situated near a rich shoal area, and its repeated use might be tied more to social than to economic factors (Morey et al., 1999). As Crothers (1999:250) has argued, for example, the Green River sites were as much part of a cultural landscape as they were of the physical landscape, and some sites probably were venerated, virtual shrines to the lineage that began using those places hundreds or even thousands of years earlier.

Alternatively, we noted that Webb's site supervisor, a geologist, described the knoll upon which the site was built as part of a levee that once was the main bank of the river (see Webb, 1946:117). In his judgement, the main channel probably did not flow past the site during its occupation, but rather Oh2 was adjacent to an oxbow lake or cutoff meander. To the north and east is a slough that probably carried water prehistorically, although it is essentially dry today because of the historic construction of a drainage ditch (see Figure 4). Thus, we wondered whether Indian Knoll was situated with respect to a different kind of resource-rich zone, an elevated area nearly circumscribed by river, stream, and wetland habitat, including a backwater lake or meander (Morey et al., 1999). Fenton et al. (1999) converged on a similar scenario, and such speculations continue to appear plausible when one considers the location of the site with respect to present topography (Figure 4).

With little question, Indian Knoll was an important site in prehistory. In hindsight, however, the speculative scenarios noted above, including the perception of this site as the focus of an extinct cultural system, are inspired more by the importance of Indian Knoll in the history of North American archaeology, than in any compelling demonstration of its actual role in prehistory. Moreover, in the absence of empirical data to resolve basic questions about the site's physiographic setting in prehistory, including its proximity to the main channel and the nature of the channel itself, such scenarios are intuitively appealing. Below we describe recent field reconnaissance at Indian Knoll and present new geoarchaeological and zooarchaeological data bearing on fundamental questions about the site's physiographic setting.

FIELD RECONNAISSANCE AT INDIAN KNOLL

Data summarized here were collected during three brief field trips to Indian Knoll in 1998 and 1999. The first, a one-day reconnaissance conducted by Fenton and colleagues, was carried out in November 1998. During this field investigation, a Total Station was used to map site topography for comparison with the WPA map (Figure 5), to establish a site datum, and to identify contemporary landmarks (river bank, field edges, etc.) that might help to re-locate the WPA excavation block. The team then used an Oakfield sediment corer to identify the location of the WPA excavation block and distinguish intact deposits around its periphery. Two transects (labeled E*n* and W*n* in Figure 5) were made along the long axis of the mound with all core locations being keyed to the site map. The second trip was a one-day visit on July 2, 1999, in which all the authors (except Herrmann) participated, at which time additional subsurface tests were conducted, along with surface collections. Because the site was in tall corn, no proveniences could be accurately established for sampling transects. We were not sure when another opportunity to collect surface samples would arise; therefore, we proceeded with these collections. It should be noted that most if not all specimens that were collected from

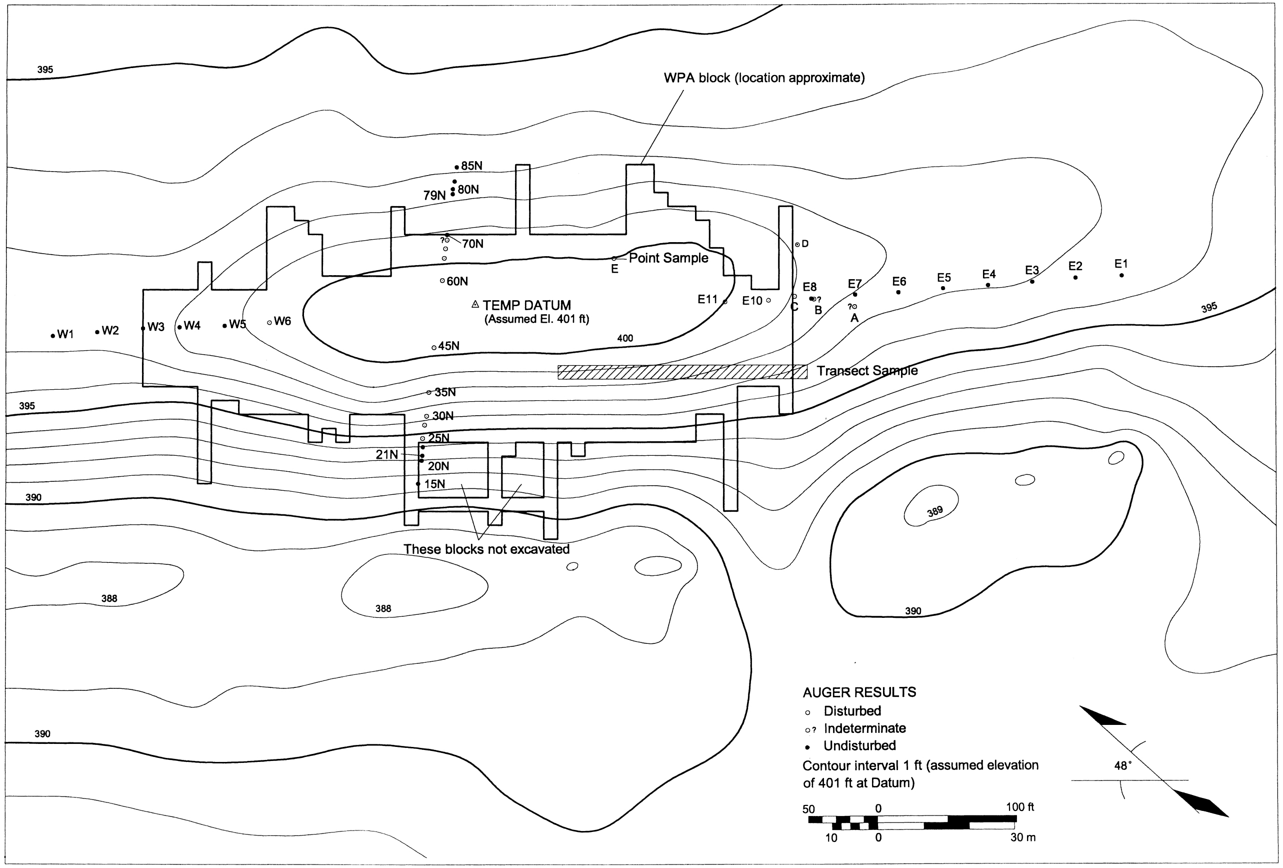

Figure 5. Modern contour map of Indian Knoll, with *approximate* locations of WPA-excavated block and trenches, our recent coring test transects, and our surface collections superimposed.

the surface originated within the WPA excavation block and were, therefore, already in secondary contexts. Lack of provenience control for these samples is unfortunate but for present purposes is only a minor inconvenience.

Surface collections focused on the retrieval of identifiable bivalve shells (see below) for paleoenvironmental analysis and lithic items (not reported here). These collections were made along three transects each approximately 50–65 m long and 5–6 m wide, following corn rows parallel to the major contours of the site area. Two transects along the downslope portions of the site yielded small, badly degraded shell pieces, most of which were not identifiable. The third transect approached the apex of the midden, and yielded many larger shell pieces in better condition. The approximate location of this third transect is shown in Figure 5, and identifiable shell specimens collected from it are analyzed below, referred to as the *transect sample.* We infer that the downslope transects consisted mostly of materials that had originally been exposed upslope much earlier and had washed downslope over the years. The upslope transect appears to include more shells that have been exposed recently, probably as plowing turns over new soil.

In addition to surface collections, preliminary subsurface testing using an Eijkelkamp hand auger with a 7 cm diameter Edelman-style auger head was made in July, although as previously noted the height of the corn crop at that time prohibited provenience control over test locations. Hence, a second campaign of systematic auger testing was carried out during the first week of November 1999, after crops were out and our auger locations could be mapped. The purpose of this testing program was fourfold. First, we sought further clarification for the boundaries between disturbed and undisturbed deposits, with the possibility of future test excavations in mind. Second, from undisturbed contexts, we hoped to retrieve sufficient charcoal samples for radiocarbon dating. Third, from the retrieved sediment cores, we wanted to establish the nature of the depositional environment, specifically whether the site was immediately adjacent to the main channel of the river, or whether some kind of standing water had been there as suggested by earlier investigators (Webb, 1946:117). Finally, we sought to document the nature of different midden components, especially whether Indian Knoll, like the Big Bend middens, included a shell-free midden zone overlying the shell-bearing portions of the deposits (see Stein, 1980, 1982).

The placement of the south-north auger transect in relation to site topography is indicated in Figure 5, as are locations of other scattered tests (labeled A–E). Superimposed on contour lines and the coring grid is the inferred *approximate* location of the original 1939–1941 WPA excavation block. This location is our best fit based on results of the auger tests (see below) in relation to original site topography (Webb, 1946: Figure 1) and present topography as depicted in Figure 5. The elevation of the contour intervals in Figure 5 are scaled to approximate Webb's contours using an assigned elevation of 401 ft (122.2 m) at a temporary datum on top of the mound. We estimate the true location of the WPA block may be as much as 5 m in any direction from the approximate location depicted in Figure 5. More precise location of the original WPA excavation will be established only by use of geophysical techniques and exploratory excavation.

In addition to subsurface testing and mapping, circumstances at Indian Knoll made possible the collection of another substantial sample of identifiable bivalve shells. Sometime between our July and November visits, looters had dug a crude rectangular hole into the deposits (ca. 1.8 × 1.3 m on each side and just over 1 m deep). The landowner had subsequently filled the hole, but around the edges and in the backdirt smear that was left behind were many well-preserved shells. We are happy to report that our subsurface auger test near this pit revealed that the vandals had spent several hours digging in WPA backdirt. The looters probably found little to interest them, but we took the opportunity to collect several hundred shell specimens that had been discarded once in prehistory, again in 1939–1941, and once again in 1999. In our analysis of shell specimens, this sample is referred to as the *point sample* and corresponds to auger location E in Figure 5.

RESULTS: GEOARCHAEOLOGICAL TESTING

Auger Sample Processing

Based on the auger results, two locations (21N and 79N) were selected to obtain samples for chemical analysis and radiocarbon assay (refer to Figures 5 and 6). We identified these locations as outside the WPA excavation on the basis of intact sedimentary and pedogenic structures seen within the augered material and selected them because their position along the south–north transect (one on the bank side and one on the opposite side of the midden) could be compared to samples analyzed from other middens in the Big Bend.

Samples were collected from these two locations by bagging sediment from the head of the auger each time it was extracted. Exact depths were recorded for each sample. The head of the auger is about 10 cm long, but because of rocks, shell, and uneven pore spaces, the depths were not exactly 10 cm for each sample. Fifteen samples were collected to a depth of 103 cm for 21N, and 10 samples to a depth of 70 cm for 79N. Because these are not great depths, we originally augered quite deeply for that very reason. In the Ohio, Illinois, and Mississippi drainages, we would have expected greater depths, but in the Big Bend we encountered bedrock at 4 or 5 m. Hydraulic augering might permit deeper penetration, but there is no indication that the results would be worthwhile.

For the chemical analysis, only the portion of the sample smaller than 1 mm (the portion falling through the 1 mm mesh screen) was used. This sand/silt/clay portion was ground with a mortar and pestle and analyzed for organic matter and carbonate content using the Loss-on-Ignition (LOI) technique (Stein, 1980, 1984). This procedure calls for sediment to be weighed before and after burning at 350°C and weighed again after burning at 1000°C. This technique works well for sediments with less than 5% clay. Sediments with more than 5% clay do not give accurate results because the heating drives off interstitial water held in clays that can be misinterpreted as organic matter or carbonates. These characteristics were chosen

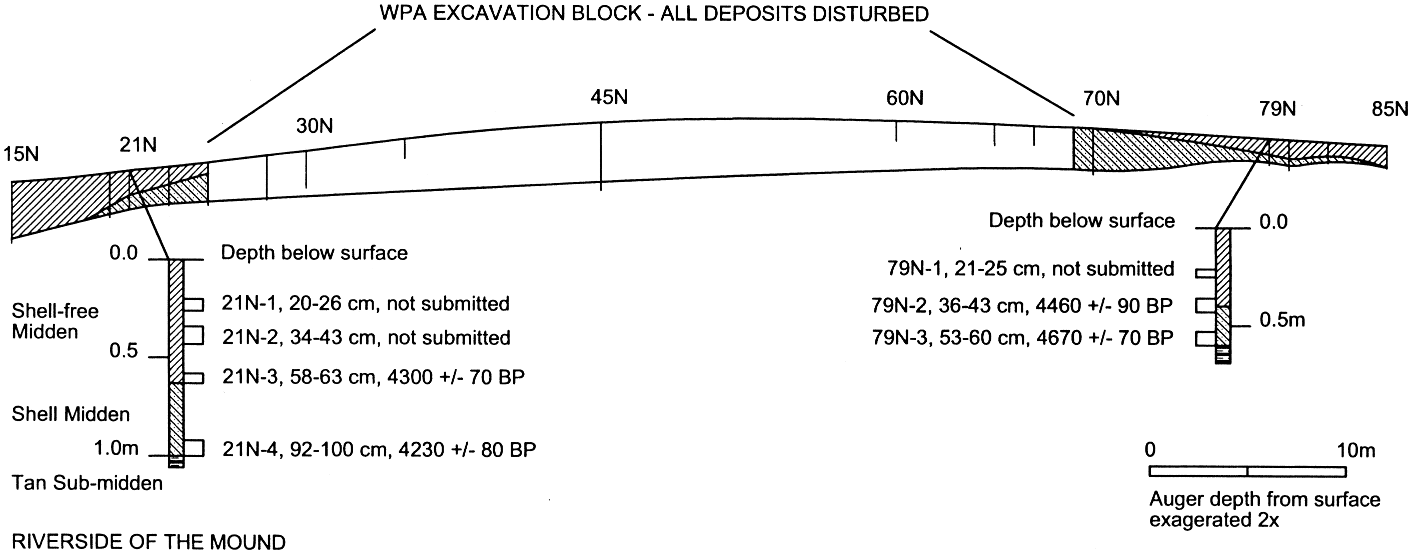

Figure 6. Idealized profile of Indian Knoll from north-south auger transect showing WPA excavation in relation to undisturbed midden deposits.

to compare Indian Knoll samples to those from shell mounds in the Big Bend and because they have proven helpful in distinguishing shell midden, shell-free midden, plowzone, and other contexts.

For the radiocarbon analysis, samples from four of the depths were selected from 21N and three from 79N to obtain charcoal. Ultimately, due to limited funds, charcoal from only four samples was submitted: 21N-3 (58–63 cm below surface), 21N-4 (92–100 cmbs), 79N-2 (36–43 cmbs), and 79N-3 (53–60 cmbs). Charcoal from these proveniences was sent to IsoTrace Radiocarbon Laboratory, University of Toronto. These samples were selected to date the upper and lower depositional context of the shell-bearing layer. It should be emphasized that the upper, relatively shell-free midden zone has not been dated.

The sediment samples were processed for the radiocarbon analysis by opening the sample bags and slowly air-drying over several days in the laboratory. The dry sediment was then screened through nested sieves of 6.3, 2.0, and 1.0 mm size mesh. Dirt clods were broken up in the 6.3 mm screen only. Charred plant material was sorted from all screen sizes but not from the less than 1 mm fraction, which was subjected to chemical analysis. Flecks of wood charcoal were common in the matrix; however, most of the charred material was small fragments of dense nutshell, apparently a combination of hickory (*Carya* sp.) and walnut (*Juglans* sp.)

Sediment Chemical Results

The LOI data appear in Table I and Figure 7 and allow us to determine whether undisturbed shell-free midden and shell midden is located at Indian Knoll. The data also allow us to compare this mound to the Carlston Annis mound in the Big Bend.

For auger location 21N, the organic matter (OM) percentages are between 5% and 6% to the depth of 20 cm (presumably the plowzone). Underneath the plowzone, the highest OM percentages of 8–9% (with one exception of 5.97%) appear until roughly 86 cm below the surface. The percentages drop to 6% and 5% at the bottom of the auger. The highest levels of OM are associated with the levels containing artifacts, charcoal, and fire-cracked rock and are interpreted as indicating undisturbed midden.

In auger location 21N, the carbonate ($CaCO_3$) data complement the changes seen in OM with intermediate percentages (around 15%) in the upper 20 cm, falling to 5% at 20–58 cm below the surface. The low carbonate percentages are associated with layers that have no shell. The carbonate increases at 58 cm and rises markedly until 100 cm below the surface where it drops again.

Carbonate determination of the fine fraction is a better measure of undisturbed shell midden than is visual observation because it is more objective. Visual inspection informs one only what the gravel fraction is. The chemical measure informs about the finer fraction as well, and thus the total content. Shell can come from mixing in rodent holes, plowing, WPA backfilling, or the augering process. The carbonate percentage measured in the fine-grained fraction is the most accurate test of whether shell was originally present, or was added from other sources.

Table I. Loss on Ignition (LOI) results for Indian Knoll, Auger Samples 21N and 79N.

	Depth (cm below surface)	Percent Organic Matter	Percent Calcium Carbonate
Auger Sample 21N			
Plowzone	0–11	5.95	16.34
	11–15	5.03	17.96
	15–20	5.52	17.52
Shell-free midden	20–26	7.74	7.85
	26–34	7.84	5.26
	34–43	8.90	4.39
	43–51	7.97	4.77
	51–58	8.06	5.29
Shell midden	58–63	8.17	16.84
	63–75	5.97	46.86
	75–86	8.53	51.09
	86–90	6.02	42.40
	90–92	5.54	37.71
	92–100	4.97	49.30
Submidden	100–103	5.82	4.85
Auger sample 79N			
Plowzone	0–17	7.05	15.44
	17–21	7.84	15.76
Shell-free midden	21–25	6.75	10.27
	25–27	7.30	12.39
	27–36	6.97	17.35
Shell midden	36–43	5.78	38.40
	43–53	4.80	32.52
	53–60	4.47	25.77
Submidden	60–70	2.84	11.72
	70–79	2.54	5.64

These data suggest that at the location 21N (on the side of the mound toward the river), nondisturbed shell midden was originally laid down on river/lake sediment and is still undisturbed (refer to Figure 6). The shell midden here is roughly 40 cm thick (defined from six samples taken between 58 and 100 cm below the surface) with an average OM content of 6.5% and carbonate of 40.7%. About 60 cm of shell-free midden is deposited above the shell midden (defined from five samples taken between 20 and 58 cm below the surface) with an average OM content of 8.1% and carbonate of 5.5%. At some point, the upper portion of this shell-free midden was mixed and plowed (defined from three samples taken between 0 and

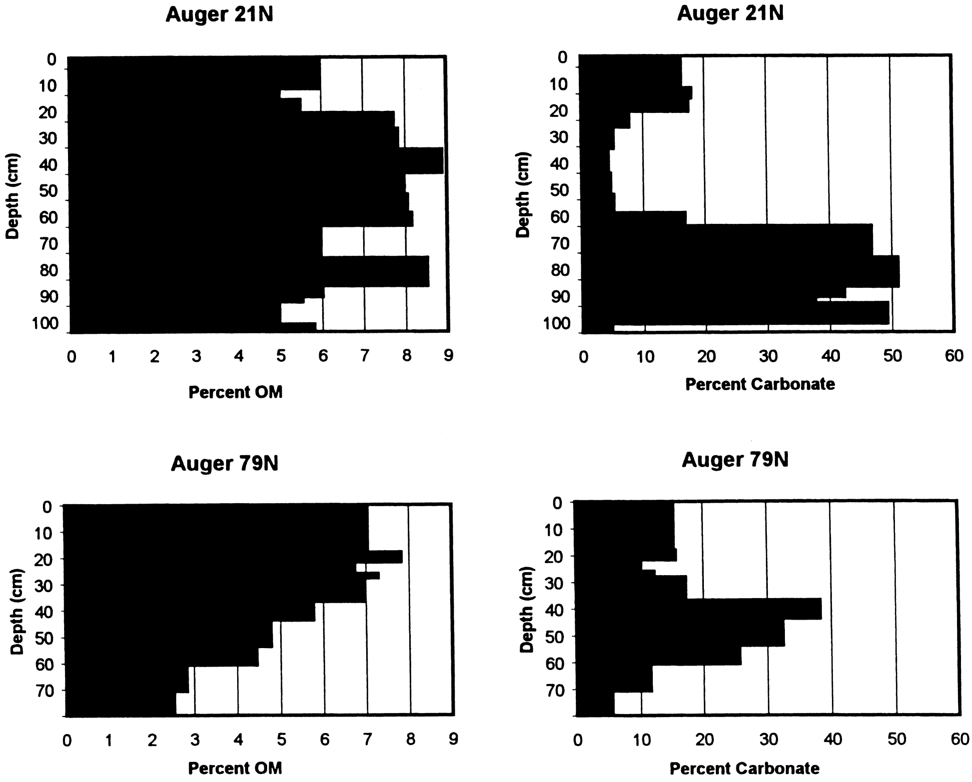

Figure 7. Bar graph of Loss on Ignition results by depth for auger location 21N and 79N.

20 cm below the surface) with an average OM content of 5.5% and carbonate of 17.3%.

In auger hole 79N, a slightly different profile is seen; layers are thinner overall and differences in OM and $CaCO_3$ less distinct between layers (Figure 7). The organic matter percentages are highest at the surface and decrease gradually with depth. This OM profile is typical for an undisturbed soil. High levels (7%) of organic matter in the samples from the upper 36 cm indicate a contribution from culturally-derived organic matter. Only once is 8% reached in this location (a level measured for undisturbed midden in the other auger location). Carbonate percentages of approximately 15% are detected to a depth of 21 cm. These levels are similar to those of the samples from the plowzone in the auger 21N location. Between 21 and 36 cm, the carbonate percent ranges from 10% to 17%, higher than the shell-free midden in 21N but significantly lower than the shell midden average of 32.2%. At 36 cm below the surface to a depth between 60 and 70 cm, the carbonate levels indicate undisturbed shell midden.

At location 79N (opposite the river-side of the mound), undisturbed shell midden has been covered by a thin shell-free midden (defined from three samples taken between 21 and 36 cm below the surface) that has an average OM content of 7.0% and carbonate content of 13.3%. The shell midden is difficult to identify, but is roughly 24 cm thick (defined from three samples taken between 36 and 60 cm below the surface) with an average OM content of 5.0% and carbonate of 32.2%.

Comparing Sediment Analysis of Indian Knoll and Carlston Annis Sites

In Table II, the average percentages for samples taken from the auger location at 21N at Indian Knoll are compared to the averages for all samples taken from the Carlston Annis mound (15Bt5; data from Stein [1980]). From these comparisons, one can see that in every stratigraphic layer, Indian Knoll has higher percentages of organic matter than the percentages at the Carlston Annis mound. Indian Knoll also has higher percentages of $CaCO_3$ in the plowzone. The slight difference in carbonate in the shell-free midden is not significant given the precision of the method.

The explanation for the higher percentage of organic matter at Indian Knoll is not immediately obvious. Two explanations come to mind. The occupants of Indian Knoll may have deposited material that is more organic in the original depositional event than what the occupants at the Carlston Annis mound deposited. A few problems are associated with this explanation. Middens at both locations have similar artifacts, burials, and charcoal present, so why would one contain more organic matter? Organic material decomposes rapidly in the Green River alluvial environment and significant time has elapsed for decomposition to occur. Both middens should have lost the same amounts of organic matter, especially in the plowzone. Farming practices may have differed at the two locations, but both have been actively farmed for about the same length of time.

Another explanation for the difference in organic matter is that Indian Knoll has a finer-grained sediment than Carlston Annis, and the additional clay and silt binds more organic matter within the deposits and prevents leaching (Stein, 1992). The Carlston Annis mound is located in the section of the Green River called the delta of Green Lake (refer to Figure 2). This delta portion of the lake received a larger proportion of coarser-grained sediment from the Upper Green than did the Indian

Table II. Comparison of percent organic matter and calcium carbonate between Indian Knoll and Carlston Annis.[a]

	Plowzone		Shell-Free Midden		Shell Midden	
	Indian Knoll	Carlston Annis	Indian Knoll	Carlston Annis	Indian Knoll	Carlston Annis
% Organic matter	5.5	5.0	8.1	5.4	6.5	4.2
% Calcium carbonate	17.3	4.3	5.5	3.1	40.7	41.4

[a] Average percentages for samples from Auger location 21N at Indian Knoll and average percentages for all samples from Carlston Annis (data from Stein [1980]).

Knoll locale, which is well within the Lower Green proper. Also, sandstone bedrock outcrops in many locations in the Big Bend, but there are few or no bedrock outcrops today around Indian Knoll. The grain-size was not measured at Indian Knoll, but field descriptions indicate a finer-grained texture than the sediments analyzed at Carlston Annis mound. These observations lead us to suggest that the interpretation of finer-grained sediment influencing the organic matter content is the correct one, and appears to be corroborated by the paleoenvironmental reconstruction based on identified mussel species from the site (see below).

Radiocarbon Determinations

Table III shows the radiocarbon sample parameters and assay results. The calibrated range is the 95% confidence interval or 2σ limit for a normal distribution obtained from intercepts with the dendro calibration curve (Standard data set INTCAL98 [Stuiver et al., 1998]; Method A, University of Washington, Quaternary Isotope Lab radiocarbon calibration program CALIB 4.3 [Stuiver and Reimer, 1993]). The dates are tightly clustered with a maximum range from 5590 to 4530 cal yr B.P. (3640–2580 B.C.).

The two determinations from auger 21N are inverted from their stratigraphic position, but overlap significantly in their calibrated age ranges. The bankside contours at 21N (refer to Figure 5) are relatively steep compared to deposits away from the bank, and colluvial action may account for some re-deposition of younger and older material along the bank face of the midden. The determinations from 79N are stratigraphically in sequence, but also overlap significantly at the 2σ range.

Table III. Accelerator mass spectrometer radiocarbon assays from auger samples.[a]

Auger Sample	Depth (cm below surface)	Weight Submitted (mg)	Weight Used (mg)	IsoTrace Lab No.	Sample Age (yr B.P. ± 1s)	95% Confidence Interval Calibrated Range yr B.P. (rounded to nearest 10)
21N-3	58–63	440	227	TO-8794	4300 ± 70	5040–5010 5000–4810 4760–4700 4670–4650
21N-4	92–100	120	102	TO-8793	4230 ± 80	4970–4470 4560–4530
79N-2	36–43	710	217	TO-8792	4460 ± 90	5440–5420 5320–4840
79N-3	53–60	190	189	TO-8791	4670 ± 70	5590–5290 5160–5140 5100–5090

[a] Material is predominantly *Carya* sp. and *Juglans* sp. charred nutshell. Corrected for fractionation to a base of δ^{13} C = −25‰. Sample age is uncalibrated conventional radiocarbon date in years before present (BP), using the Libby ^{14}C meanlife of 8033 years. 95.5% confidence interval calibrated with the standard data set INTCAL98 (Stuiver et al., 1998).

It appears from the radiocarbon determinations that the primary shell accumulation was aggrading between 5600 and 4600 yr B.P. (3650–2650 B.C.). The true length of aggradation is probably more on the order of 400–500 years within this maximum 1000-year interval.

Figure 8 graphically summarizes calibrated radiocarbon ages from all the dated Green River Archaic sites. Details of the radiocarbon determinations can be found in Crothers (1999: Table 5.12). Two additional radiocarbon assays have been made for Indian Knoll burials (Herrmann, 2001). One of the burials fits well within the major shell-depositional period; the second burial is some 500 years after shell deposition. It is apparent from Figure 8 that occupation of the various Archaic midden sites took place over a considerable time span, but shell accumulation appears to be most intense from approximately 6500 to 4500 yr B.P. That these sites continued to be used at least sporadically is not surprising. Many of the sites contain minor amounts of Woodland and late prehistoric period pottery and diagnostic projectile points in their upper deposits. The early dates from the Kirkland site (15McL12) are also intriguing (all dates were made on bone or charcoal from burial contexts). Clearly, much more work must be done to delineate the depositional contexts, and to date the Green River Archaic Period definitively.

RESULTS: ANALYSIS OF SHELLFISH SAMPLES

Patterns of Taxonomic Representation

Table IV presents numbers of identified valve specimens (NISP) for the transect and point samples at Indian Knoll, together with comparative data from controlled excavations at the Haynes midden in the Big Bend (Morey and Crothers, 1998). Identifications are restricted to valves with most of the beak/umbo region intact and were made by comparison to recent reference specimens curated by Morey, in consultation with published guides (e.g., Burch, 1975; Cummings and Mayer, 1992; Watters, 1995; Parmalee and Bogan, 1998). All identified taxa from Indian Knoll are documented historically in Green River (Price, 1900; Ortmann, 1926; Clench and van der Schalie, 1944; Stansbery, 1965; Williams, 1969; Cicerello et al., 1991), although at least two extinct species from the Haynes midden are known, in this drainage, only from archaeological samples. Terminology follows Turgeon et al. (1998; see also Cummings and Mayer [1992]), with the exception of the distinctive shell of the presumably extinct *Epioblasma phillipsii*, which is not listed by Turgeon et al. (1998) or by Cummings and Mayer (1992) but is regarded as a valid species in Cumming and Mayer's later work (1997; see also Watters [1995: 47]). In addition, several "form" distinctions are called for by the procedure for analyzing taxonomic representation.

The Indian Knoll samples ($n = 918$) yielded 20 identified taxa, whereas the much larger Haynes sample ($n = 4455$) includes 35 taxa. Given the sample size disparity, there is no point in searching for meaningful contrasts where taxa are absent from Indian Knoll but represented by one or a few valves at Haynes (Grayson, 1984). However, several taxa that are well represented at one or the other site exhibit

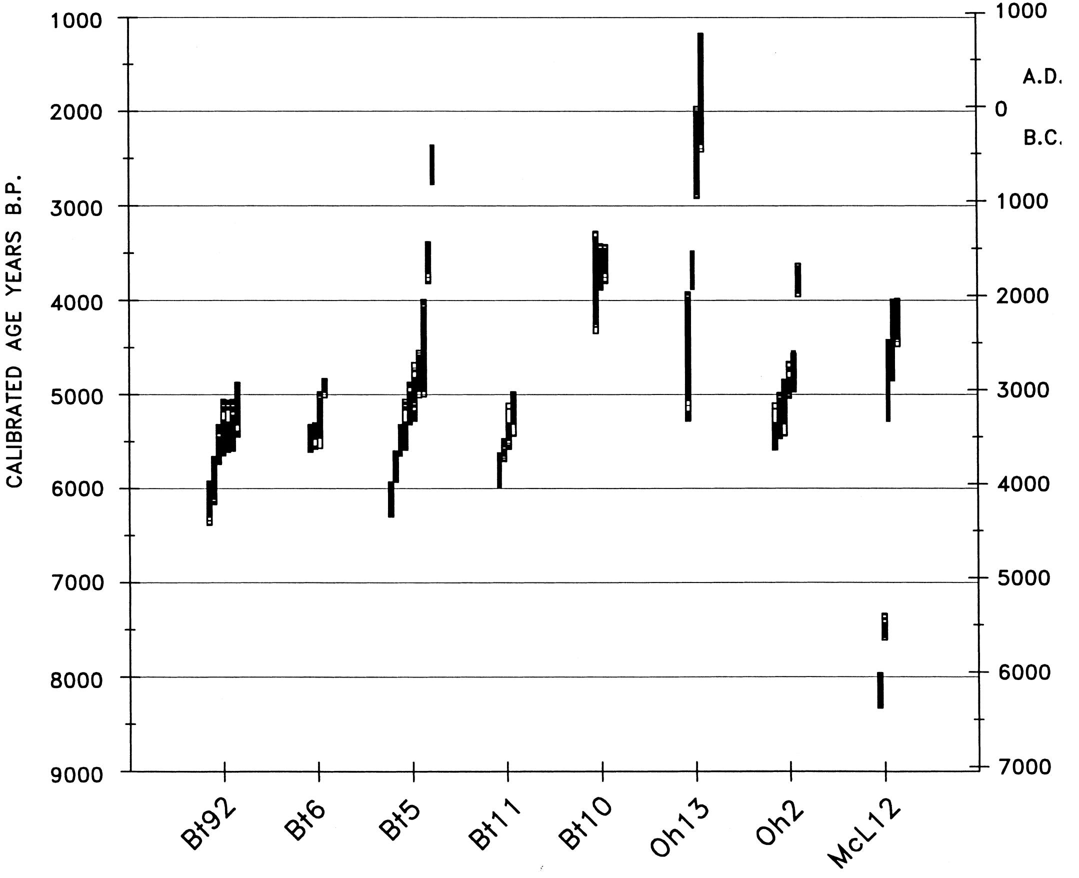

Figure 8. Calibrated radiocarbon age ranges (2σ) for Green River Archaic sites: (15Bt92–York-Render; Bt6–DeWeese; Bt5–Carlston Annis; Bt11–Haynes; Bt10–Read; Oh13–Bowles; Oh2–Indian Knoll; McL12–Kirkland).

Table IV. Number of identified mussels per taxon from two Indian Knoll surface collections, and from excavated samples at the Haynes midden (data from Morey and Crothers [1998]).

		Indian Knoll		
Taxon	Haynes Unit A1	Transect	Point	Total (Indian Knoll)
Actinonaias ligamentina form *ligamentina* (Mucket)	133	0	1	1
Amblema plicata form *costata* (Three-Ridge)	49	3	7	10
Cumberlandia monodonta (Spectaclecase)	4	0	0	0
Cyclonaias tuberculata (Purple Wartyback)	169	5	10	15
Cyprogenia stegaria (Fanshell)	243	18	16	34
Ellipsaria lineolata (Butterfly)	23	10	10	20
Elliptio crassidens (Elephant Ear)	102	38	42	80
Elliptio dilatata (Spike)	736	17	32	49
Epioblasma personata (Round Combshell)	14	0	0	0
Epioblasma phillipsii (Cincinnati Riffleshell)	8	0	0	0
Epioblasma torulosa rangiana/propinqua/obliquata (Northern Riffleshell/Tennessee Riffleshell/Catspaw)	843	8	8	16
Epioblasma triquetra (Snuffbox)	6	0	0	0
Fusconaia subrotunda (Long-Solid)	291	29	33	62
Hemistena lata (Cracking Pearlymussel)	6	0	0	0
Lampsilis abrupta (Pink Mucket)	1	0	0	0
Lampsilis fasciola (Wavy-Rayed Lampmussel)	2	0	0	0
Lampsilis ovata (Pocketbook)	12	0	0	0
Lasmigona costata (Fluted Shell)	3	0	0	0
Ligumia recta (Black Sandshell)	12	0	0	0
Obliquaria reflexa (Three-Horned Wartyback)	19	6	2	8
Obovaria retusa (Ring Pink)	341	38	27	65
Obovaria subrotunda form *subrotunda* (Round Hickorynut)	241	31	57	88
Plethobasus cooperianus (Orange-Foot Pimpleback)	6	0	1	1
Plethobasus cyphyus (Sheepnose)	6	0	0	0
Pleurobema sintoxia (Round Pigtoe)	17	0	0	0
Pleurobema cordatum (Ohio Pigtoe)	209	22	32	54
Pleurobema plenum (Rough Pigtoe)	0	86	121	207
Pleurobema rubrum (Pyramid Pigtoe)	719	80	102	182
Potamilus alatus (Pink Heelsplitter)	6	0	0	0
Ptychobranchus fasciolaris (Kidneyshell)	85	1	5	6
Quadrula cylindrica (Rabbitsfoot)	16	0	0	0
Quadrula metanerva (Monkeyface)	6	1	0	1
Quadrula pustulosa (Pimpleback)	116	8	10	18
Strophitus undulatus (Creeper)	2	0	0	0
Tritogonia verrucosa (Pistolgrip)	9	0	1	1
Truncilla truncata (Deertoe)	8	0	0	0
TOTAL	4455	401	517	918

disparities that almost certainly are substantive. When evaluating these patterns, recall that previous analysis of the Haynes shells yielded an unequivocal river shoal signature, meaning modest depths between roughly 0.5 and 2 m, with a swift current over sand and/or gravel substrate (Morey and Crothers, 1998). Patch (1976) came to a similar conclusion for the Carlston Annis shell assemblage.

First, *Actinonaias ligamentina* was identified only once in the Indian Knoll sample, but is represented by 133 valves at Haynes. *Actinonaias ligamentina* is most strongly associated with water depths less than 2 m, swift-to-moderate current velocity, and gravel or sand substrates (Parmalee and Bogan, 1998:53; Warren, 1991: 32). This species is common today in the shallow shoals of the upper Green where it appears to be dominant. Also noteworthy are the reversed proportions of *Elliptio dilatata* and *Elliptio crassidens*, the former strongly dominant in the Haynes sample, the latter more abundant at Indian Knoll. *Elliptio dilatata* exhibits habitat associations similar to those of *A. ligamentina*, whereas *E. crassidens* is distinguished by its scarcity in shallow waters and routine presence in waters exceeding 2 m (Warren, 1991:31; Parmalee and Bogan, 1998:79). It should be noted, however, that *E. crassidens* has a larger, more robust shell than *E. dilatata*, and many of the *E. crassidens* specimens identified from Indian Knoll are large valve fragments that routinely display evidence of having been struck by plow blades or other farm machinery parts. *Elliptio dilatata* valves may be more vulnerable to modern farming activities than are those of *E. crassidens.* Additional considerations, however (see below), suggest that the difference in representation between these two species is, in fact, substantive.

A striking disparity in taxonomic representation concerns the riffleshell complex, *Epioblasma rangiana/propinqua/obliquata.* This group comprises only 1.7% (n = 16) of the Indian Knoll samples, but represents almost 20% (n = 843) of the Haynes sample. The vast bulk are *E. rangiana* (see Morey and Crothers, 1998:913–915), regarded in some sources as synonymous with, or a subspecies of, *Epioblasma torulosa* (Johnson, 1978; Warren, 1991; Watters, 1995; Parmalee and Bogan, 1998). Regardless of taxonomic ambiguity, the riffleshells get their common name from their strong association with shallow, swiftly flowing waters and relatively coarse substrates (Warren, 1991:32; Parmalee and Bogan, 1998:107). One might attribute their scarcity at Indian Knoll to sampling bias, given that *E. rangiana* has a modest-sized shell, with old adults attaining a maximum length of about 65 mm (Parmalee and Bogan, 1998:106). Most individuals are substantially smaller, with correspondingly thinner, more fragile shells, and many small valves may have been destroyed over the years, or overlooked during surface collecting at Indian Knoll.

Patterns of representation among another species, *Obovaria subrotunda*, suggest that the scarcity of riffleshells is real. Like *E. rangiana*, its shell is modest-sized, seldom exceeding 60 mm in length (Parmalee and Bogan, 1998:168), and usually smaller. From the controlled excavations at Haynes, 5.4% (n = 241) of identified specimens are *O. subrotunda*, whereas from the Indian Knoll sample almost 10% (n = 88) are *O. subrotunda.* Moreover, most of the Indian Knoll specimens are small, 20–30 mm maximum length. Such shells are as fragile as *E. ran-*

giana valves of comparable size, and we conclude that the scarcity of *E. rangiana* from Indian Knoll is not an artifact of sampling bias. For the same reason, we strongly suspect that the greater representation of *E. crassidens* compared to *E. dilatata* in the Indian Knoll series is not entirely a product of sampling bias.

Finally, *Pleurobema plenum* is well represented at Indian Knoll but absent from Haynes. The apparent absence of this species at Haynes was a source of concern (Morey and Crothers, 1998:914), given that distinctions within *Pleurobema* are difficult, and that *P. plenum* is a federally endangered species for which recent comparative specimens are limited. However, this species is readily recognizable from the Indian Knoll collections, although its presence probably does not hold major paleoenvironmental implications. Like other *Pleurobema* species in these samples, *P. plenum* is a large river form that can be found under variable conditions, including water depths between about 1 and 2.5 m (Warren, 1991:32). *Pleurobema plenum* could be associated with variable current velocities, but it should be noted that *Pleurobema rubrum*, strongly associated with swift currents (Warren, 1991: 32; Watters, 1995:81; Parmalee and Bogan, 1998:193), is also well represented at Indian Knoll.

Aquatic Paleoenvironmental Analysis

The surface-collected shell samples have obvious limitations but, nevertheless, provide insights into the kind of aquatic habitat from which mussels were collected prehistorically. We use Warren's (1991, 1992) method of aquatic paleoenvironmental analysis, a procedure based on historically documented habitat associations of freshwater mussel species across four environmental variables: water-body type, water depth, current velocity, and substrate composition. Each variable has a series of different values, and for each species one of three numerical weights is assigned depending on that species' compatibility with a given value. Thus, under water-body type, a species known to occur frequently in large rivers is given a weight of 1 for that value, whereas if it occurs only occasionally in large rivers it has a weight of 0.5, and if it seldom or never is found in large rivers it has weight of 0. That same species may have identical or different weights on a different value (e.g., small river) of the water-body type variable.

A spreadsheet program, UNIO (Warren 1991, 1992), is used to tabulate frequencies of different species in a sample; alternatively, 1 or 0 can be used to signify the presence versus absence of a species. In either case, for every variable value the weights are multiplied by the number entered for each species, summed across taxa, and then re-scaled to percentage values. The result, as Warren (1991:35) summarizes, is habitat scores that "may be thought of as simply the percentage of an assemblage that is adapted to a particular habitat category." Warren's (1991) original presentation discusses in detail the strengths and limitations of this procedure (see also Warren, 1995a, 1995b).

Table V presents percentage scores for all analyses presented here. Figure 9 displays scores from the analysis of frequency (NISP) data from the two Indian

Table V. Habitat preference scores for all mussel samples analyzed, generated with the computer spreadsheet program UNIO, version 3 (Warren, 1991, 1992).

	Archaeological Samples						
	NISP Frequency Data (Percent NISP)			Presence/Absence Data			
Environmental Variable	Indian Knoll Transect	Indian Knoll Point	Haynes Unit A1	Indian Knoll Transect	Indian Knoll Point	Haynes Unit A1	Recent Sample Miller et al. (1994)[a]
Water-Body Type							
Large river	91.4	87.1	92.1	85.3	86.8	83.3	90.0
Medium river	81.7	85.1	87.5	82.4	78.9	84.6	84.0
Small river	43.8	53.2	48.7	52.9	52.6	57.7	60.0
Large creek	28.9	34.0	23.5	35.3	31.6	30.8	32.0
Small creek	2.37	3.1	9.3	8.8	2.6	16.7	8.0
Lake	0.0	0.0	0.1	0.0	0.0	1.3	8.0
Water Depth (m)							
0	21.2	25.5	55.3	35.3	42.1	51.4	64.6
0.3	31.7	35.2	68.4	64.7	63.2	83.8	77.1
0.6	49.1	48.5	81.4	82.4	78.9	91.9	85.4
0.9	95.3	95.7	98.6	97.1	92.1	93.2	97.9
1.2	83.3	85.3	84.7	79.4	76.3	85.1	93.8
1.5	83.3	85.5	84.8	79.4	81.6	86.5	89.6
1.8	77.4	74.0	69.2	67.6	68.4	77.0	75.0
2.1	75.4	72.4	50.0	61.8	63.2	71.6	70.8
2.4	75.4	72.4	49.9	61.8	63.2	55.4	70.8
2.7	24.6	24.1	25.9	44.1	47.4	47.3	62.5
3.0	24.6	24.1	25.9	44.1	47.4	47.3	62.5
3.4	23.1	22.1	21.2	32.4	39.5	32.4	52.1
3.7	23.1	22.1	21.0	32.4	39.5	29.7	43.8
4.0	20.0	17.9	9.9	26.5	31.6	25.7	37.5
4.3	20.0	17.9	9.9	26.5	31.6	25.7	37.5
4.6	20.0	17.9	9.9	26.5	31.6	25.7	37.5
Current Velocity							
Swift	100	100	99.5	100	100	93.1	74.0
Moderate	56.9	62.2	39.3	61.8	66.7	54.2	62.0
Slow	40.5	43.7	25.0	44.1	50.0	38.9	68.0
Standing	0.4	0.7	1.1	2.9	2.8	11.1	30.0
Substrate Composition							
Cobble-Gravel	69.8	70.1	68.4	61.8	55.3	60.5	34.0
Gravel	100	100	99.9	100	100	97.4	76.0
Gravel-Sand	100	100	99.8	100	100	93.4	74.0
Sand	74.7	77.6	57.3	73.5	71.1	71.1	80.0
Sand-Mud	55.7	58.5	37.0	47.1	44.7	39.5	60.0
Mud	54.9	58.3	36.5	41.2	42.1	34.2	64.0

[a] Data from Miller, Payne, and Neill (1994), live mussels collected from Green River between river miles 101.5 and 155.8 (km 163.3 and 250.7), in June and July 1992.

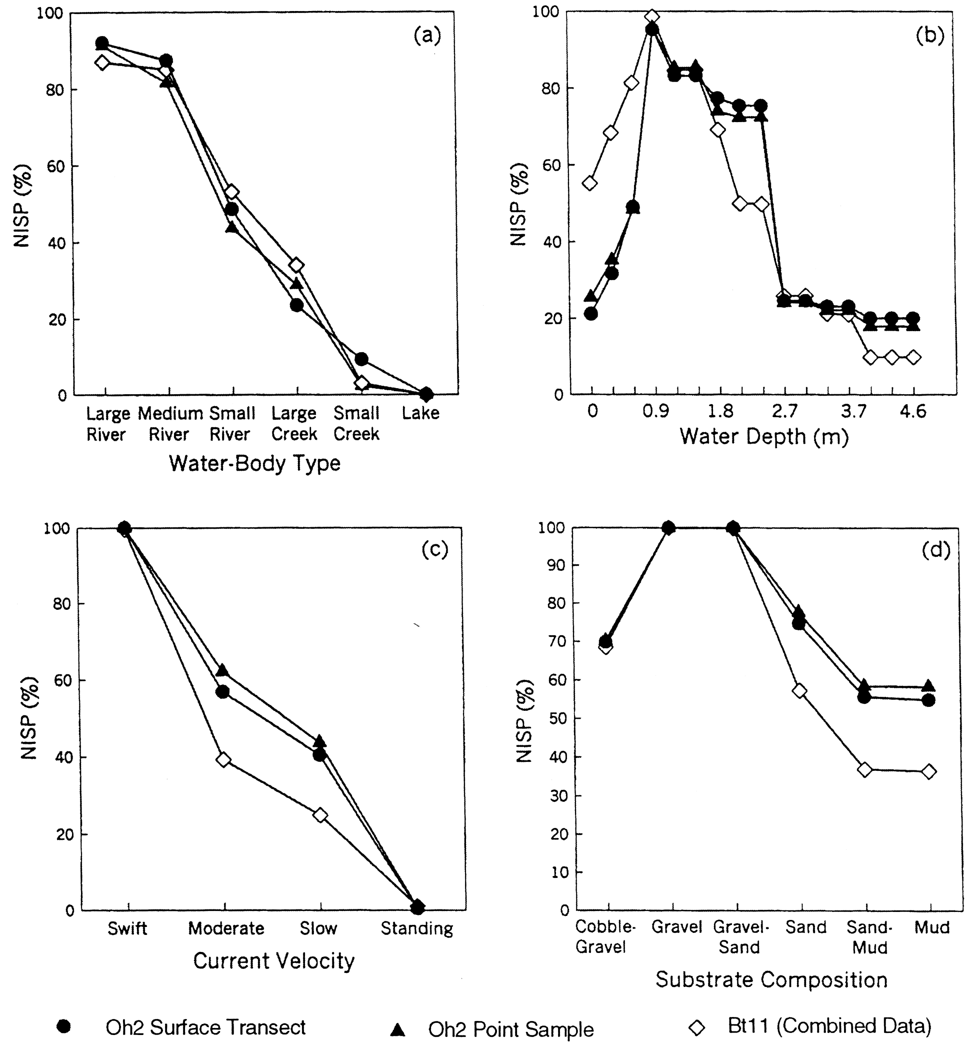

Figure 9. Habitat preference scores generated by UNIO (Warren, 1991, 1992) based on frequencies of identified freshwater mussels (NISP) from Indian Knoll surface collections, and Haynes upper and lower stratigraphic zones combined (Morey and Crothers, 1998:913). (●) Indian Knoll transect sample; (▲) Indian Knoll point sample; (◇) Haynes.

Knoll samples, and the Haynes excavated sample. On the water-body type variable (Figure 9[a]), all samples show strong correspondence to large or medium river values. On water depth (Figure 9[b]), all samples show maximum correspondence at 0.9 m, but compared to Haynes the Indian Knoll shells show markedly lower correspondence to depths less than 0.9 m, and higher correspondence to several greater depth values. The near-absence of *A. ligamentina* and *E. rangiana*, along with the strong representation of *E. crassidens*, is primarily responsible for this different response profile. Likewise, on current velocity (Figure 9[c]) all samples peak at or near 100% on swift, with the Indian Knoll shells maintaining consistently higher compatibility than Haynes with moderate and slow values. Finally, on substrate composition (Figure 9[d]) all samples show maximum (100%) compatibility with gravel and gravel-sand values, with the Indian Knoll series maintaining a stronger association than Haynes with finer-grained substrates.

Given the probable biases in the Indian Knoll sample, it is useful to balance an analysis of frequency data with one based on presence-absence data. Recording a taxon as present or absent (1 or 0) is equivalent to assuming that all are present in the same numbers. While such a pattern will never hold, this approach guards against biases that might be introduced if one or more taxa with broad habitat tolerances dominate an assemblage, potentially masking the significance of small numbers of taxa with more restricted habitat requirements. Figure 10 displays percentage scores from the analysis of presence-absence data, along with an additional comparative data set (Miller et al., 1994). The additional data are from a 1992 survey of live mussels just downstream from Dam 4, just downstream from Dam 3, and from several locations in between. The sample area thus includes the Big Bend, but stops short of the Indian Knoll area (see Figure 1). This data set provides a useful frame of reference by illustrating the response profiles that stem from modern impoundment conditions, including deeper, slower waters with relatively fine-grained substrates.

Overall, response profiles from presence-absence data suppress the differences between Indian Knoll and Haynes that were apparent from frequency data. This result is expected, given that all taxa hold equal significance under this approach. The noteworthy contrasts here are between the archaeological and recent samples. On water-body type (Figure 10[a]) there is little difference, with all samples showing maximum compatibility with the large and medium river values. On water depth (Figure 10[b]), all samples peak at 0.9 m, but the recent sample shows consistently higher compatibility than the archaeological samples with greater depths. On current velocity (Figure 10[c]), the recent sample shows lower compatibility with the swift value, but markedly higher compatibility with slow and standing values. On substrate composition (Figure 10[d]), the recent sample yields consistently lower scores on coarse-grained substrate values, but higher scores on the finest-grained substrate values, sand-mud and mud. These different response profiles stem from the presence of several deep/slow water species in modern times that are absent from the archaeological samples (e.g., *Arcidens confragosus*, *Fusconaia flava*, *Lasmigona complanata*, *Leptodea fragilis*, *Quadrula nodulata*), and the correspond-

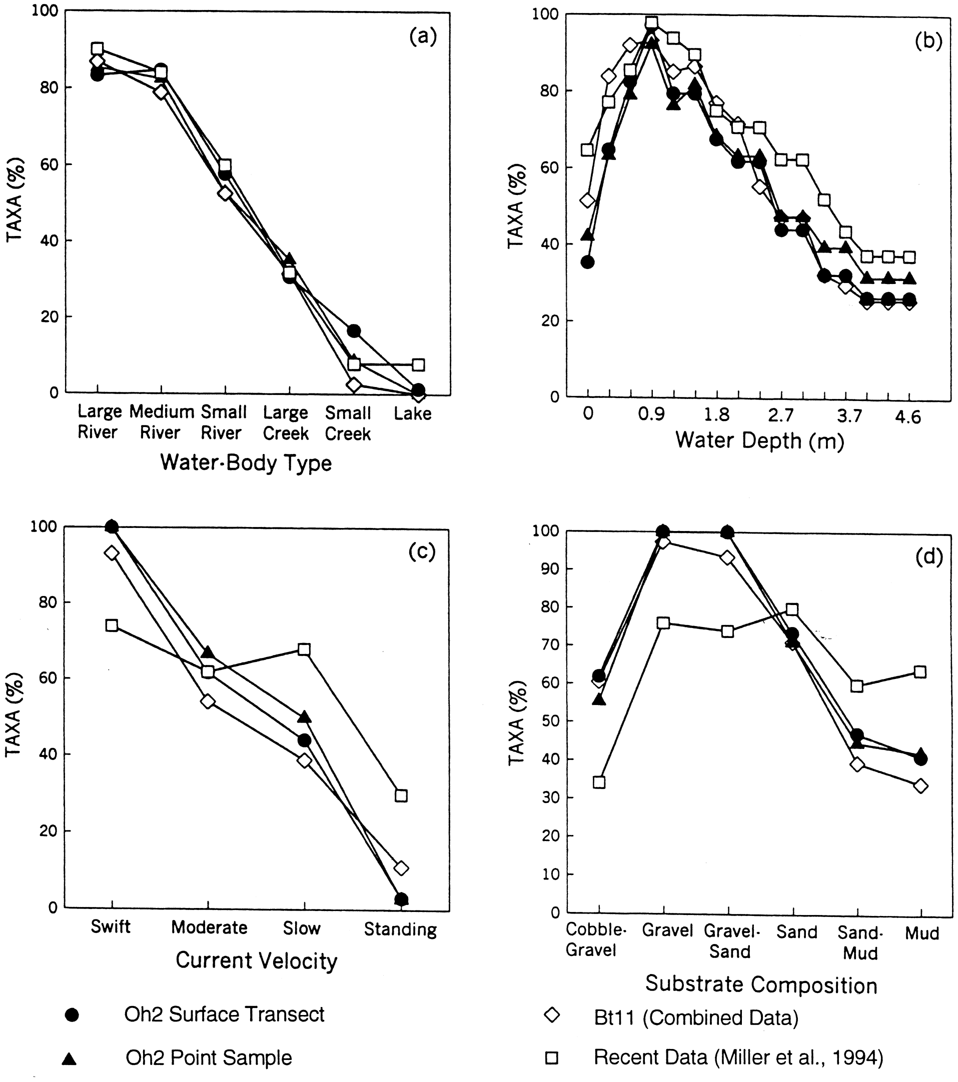

Figure 10. Habitat preference scores generated by UNIO (Warren, 1991, 1992) based on presence or absence of freshwater mussel species from Indian Knoll surface collections, Haynes upper and lower stratigraphic zone combined (Morey and Crothers, 1998:913), and from a recent survey of live mussels between river miles 101.5 and 155.8 (km 163.3 and 250.7 [Miller et al., 1994:51]). (●) Indian Knoll transect sample; (▲) Indian Knoll point sample; (◇) Haynes; (□) recent collection.

ing absence from the recent samples of certain taxa represented in the prehistoric middens (e.g., *Epioblasma rangiana*, *Cyprogenia stegaria*, *Obovaria retusa*).

In combination, results of this analysis lead to several inferences regarding the Indian Knoll shells. First, if an ox-bow lake or cutoff meander with standing water was adjacent to the site during occupation, it was not the primary source of shellfish harvested by the residents of Indian Knoll. These shells came from the main river channel, and from a setting with reasonably strong current. This inference is further strengthened by the marked difference in response profiles between Indian Knoll and recent samples that reflect impoundment conditions. On the other hand, compared to Haynes the response profiles from Indian Knoll do not necessarily suggest that collecting was restricted to a classic shoal setting, but included more varied river conditions. The stretch accessed by the people of Indian Knoll was probably characterized by deeper settings on average, with variable substrate but consistently strong current. This pattern does not in any way imply that shellfishing was an ancillary concern to the people of Indian Knoll. Highly productive mussel-bearing stretches adjacent to Indian Knoll may have been extensive and thus not readily depleted, whereas smaller shoals associated with some sites might have yielded more concentrated but easily depleted beds. These issues await further analysis, but for the present it is sufficient to emphasize that the Indian Knoll residents, like the occupants at other Green River sites, harvested shells from a swiftly flowing, shallow to moderately deep setting of the main river channel. Shellfish resources were one reason why Indian Knoll was where it was.

CONCLUSIONS

Despite extensive excavations at Indian Knoll that disturbed a large portion of the site, significant intact deposits remain around the periphery. The sequence of strata reflect the now familiar shell midden pattern of a shell-bearing layer on top of natural river/lake sediments, and overlain by a relatively shell-free midden layer. Proportions of organic matter and calcium carbonate in deposits at Indian Knoll are similar to proportions at the Carlston Annis site, reinforcing our field interpretation that portions of the deposit are undisturbed. Overall, Indian Knoll tends to show slightly higher percent organic matter content compared to Carlston Annis. We think this is due to a higher content of fine-grained sediments at Indian Knoll, which retain more organic matter than do the coarser-grained sediments at Carlston Annis. The differences in grain size between sites is because Indian Knoll is situated on Pleistocene lake sediments in the lower Green River and Carlston Annis in the Big Bend is situated upstream in deltaic portions of Pleistocene Green Lake. Paleoenvironmental analysis of mussel shell assemblages from Indian Knoll and the Haynes site (located in the Big Bend) also reflect this difference in river substrate. The Big Bend mussel species reflect a classic river shoal—modest depth, swift current, sand/gravel substrate—compared to Indian Knoll, which reflect strong river current but deeper water on average and more variable substrate with finer-grained sediments. We are still unclear about the exact geomorphic context of the mussel bed associated with Indian Knoll. Although shellfish clearly came from the main river channel, to determine whether collecting took place in a shifting point bar or from a bedrock-controlled shoal, as is the case at Chiggerville, will require additional fieldwork.

New radiocarbon dates reported here clearly place the intensive utilization of shellfish at Indian Knoll in the late Middle Archaic to Late Archaic Period. Four radiocarbon determinations that date the upper and lower portions of the shell midden layer at Indian Knoll range from 5590 to 4530 cal yr B.P. This is well within the range of other Green River shell midden sites, which date primarily between 6500 and 4500 yr B.P. That Indian Knoll is on the later end of this sequence may have more to do with the fact that the center (and hence the oldest portion) of the site has been removed, rather than with its true maximal age.

The findings of our preliminary field investigations have encouraged us to design future research with the goal of obtaining a larger stratified sample from Indian Knoll. An excavated column will allow us to obtain comparable samples of artifacts, and botanical and faunal remains. We envision this small excavation project as part of a systematic program dedicated to examining the Green River Archaic from a multidisciplinary ecological perspective.

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