The Discovery of America

The first Americans may have swept the Western Hemisphere and decimated its fauna within 1000 years.

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America was the largest landmass undiscovered by hominids before the time of *Homo sapiens*. The Paleolithic pioneers that crossed the Bering Bridge out of Asia took a giant step. They found a productive and unexploited ecosystem of over 10^7 square miles (2.6×10^7 square kilometers). As Bordes has said (*1*), "There can be no repetition of this until man lands on a [habitable] planet belonging to another star."

At some time toward the end of the last ice age, big game hunters in Siberia approached the Arctic Circle, moved eastward across the Bering platform into Alaska, and threaded a narrow passage between the stagnant Cordilleran and Laurentian ice sheets. I propose that they spread southward explosively, briefly attaining a density sufficiently large to overkill much of their prey.

Overkill without Kill Sites

Pleistocene biologists wish to determine to within 1000 years at most the time of the last occurrence of the dominant Late Pleistocene extinct mammals. If one recognizes certain hazards of "push-button" radiocarbon dating (*2*), especially dates on bone itself, it appears that the disappearance of native American mammoths, mastodons, ground sloths, horses, and camels coincided very closely with the first appearance of Stone Age hunters around 11,200 years ago (*3*).

Not all investigators accept this circumstance as decisive or even as adequately established. No predator-prey model like Budyko's (*4*) on mammoth extinction has been developed to show how the American megafauna might have been removed by hunters (*5*). Above all, prehistorians have been troubled by the following paradox.

In temperate parts of Eurasia, large numbers of Paleolithic artifacts have been found in many associations with bones of large mammals. Although the evidence associating Stone Age hunters and their prey is overwhelming, not much extinction occurred there. Only four late-glacial genera of large animals were lost, namely, the mammoth (*Mammuthus*), woolly rhinoceros (*Coelodonta*), giant deer (*Megaloceros*), and musk-ox (*Ovibos*).

In contrast, the megafauna of the New World, very rarely found associated with human artifacts in kill or camp sites (*6*), was decimated. Of the 31 genera of large mammals (*7*) that disappeared in North America at the end of the last ice age, only the mammoth (*Mammuthus*) is found in unmistakable kill sites. The seven kill sites listed by Haynes (*8*) lack the wealth of cultural material, including art objects, associated with the Old World mammoth in eastern Europe and the Ukraine. It is not surprising that some investigators discount overkill as a major cause of the extinctions in America.

But if the new human predators found inexperienced prey, the scarcity of kill sites may be explained. A rapid rate of killing would wipe out the more vulnerable prey before there was time for the animals to learn defensive behavior, and thus the hunters would not have needed to plan elaborate cliff drives or to build clever traps. Extinction would have occurred before there was opportunity for the burial of much evidence by normal geological processes. Poor paleontological visibility would be inevitable. In these terms, the scarcity of kill sites on a landmass which suffered major megafaunal losses becomes a predictable condition of the special circumstances which distinguish a sudden invasion from more gradual prehistoric cultural changes in situ. Perhaps the only remarkable aspect of New World archeology is that *any* kill sites have been found (*9*).

Megafaunal Biomass

Bordes (*1*) and Haynes (*8*) believe that the Stone Age hunters found abundant game in America. Although the fauna was diverse (*7*), no estimates of the size of the Late Pleistocene game herd have been attempted. I propose two crude but independent methods of estimating the biomass of the native megafauna, both of which utilize present range-carrying capacity. In the first method one projects estimates of the biomass of large mammals in African game parks to areas of comparable range productivity in the New World. The other method is based on the assumption that present managed livestock plus game populations in the Americas would equal, and probably exceed, the maximum herd size of the Late Pleistocene.

Estimates of biomass in various African parks are shown in Table 1. The drier parks such as Tarangire Game Reserve, Kafue, Kagera, and others not included in Table 1 such as Kruger National Park, South Africa, and Tsavo National Park, Kenya, support 10 to 20 animal units (*10*) per section (1.8 to 3.5 metric tons per square kilometer). In the Americas during the Pleistocene, similar values might be expected on drier ranges (mean annual precipitation, 400 to 600 millimeters) dominated by mammoth, horse, and camel. The carrying capacity would have been much less in the driest regions (annual precipitation less than 200 millimeters).

African game parks supporting the highest biomass, over 100 animal units per section (over 18 metric tons per square kilometer), occur in tall grass savannas along the margin of wet tropical forest. The dominant species are elephant, buffalo, and hippo. In the tropical American savannas, along coasts, and on floodplains of the temperate regions, one might expect a similar biomass in the Pleistocene. The dominant species were mastodons and large edentates.

For the 3×10^6 sections of land

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Table 1. Large mammal biomass in some African parks and game reserves [from Bourliere and Hadley (*32*)]. [Courtesy of Annual Reviews, Inc., Palo Alto, Calif.]

Location	Habitat	Number of species	Biomass (metric tons per square kilometer)	Biomass (animal units per square mile)
Tarangire Game Reserve, Tanzania	Open *Acacia* savanna	14	1.1	6
Kafue National Park, Zambia	Tree savanna	19	1.3	7
Kagera National Park, eastern Rwanda	*Acacia* savanna	12	3.3	18
Nairobi National Park, Kenya	Open savanna	17	5.7	32
Serengeti National Park, Tanzania	Open and *Acacia* savannas	15	6.3	36
Queen Elizabeth National Park, western Uganda	Open savanna and thickets	11	12	68
Queen Elizabeth National Park, western Uganda	Same habitat, overgrazed	11	27.8–31.5	158–179
Albert National Park, northern Kivu	Open savanna and thickets, overgrazed	11	23.6–24.8	134–141

(7.8×10^6 square kilometers) in the unglaciated United States, I propose the following average stocking capacities, each covering roughly 10^6 sections: (i) savannas, forest openings, floodplains, and other highly to moderately productive habitats, 50 animal units per section, or 22.7×10^6 metric tons; (ii) arctic, boreal, semiarid, short grass ranges, and other low to moderately productive habitats, ten animal units per section, or 4.6×10^6 metric tons; (iii) closed canopy forest, extreme desert, barren rock, and other habitats unproductive for large herbivores, two animal units per section, or 0.9×10^6 metric tons. The total for North America north of Mexico is 62×10^6 animal units or 28.2×10^6 metric tons.

Turning from the African analogy to estimates based on current livestock plus game populations, one obtains a higher biomass. The United States alone supported 1.20×10^8 animal units (all types of livestock) in 1900 and 1.48×10^8 in 1945. Adding wild game, I project these values for the Western Hemisphere south of Canada to a total of 5.00×10^8 animal units, or 2.30×10^8 metric tons (*11*). Presumably this value, based on managed herds, exceeds the natural Pleistocene biomass.

A herd of 2.50×10^8 animal units during the Late Pleistocene would seem more realistic in terms of the African values. A hemispheric estimate of 10^8 animal units should be far too low for the primary plant productivity available to the native herbivores but would still be a sizable resource for the first Paleolithic hunters.

The alternate view, that the American large mammal biomass was in eclipse during the late glacial (*12*), cannot be tested quantitatively on the basis of fossils alone. Bones do not provide reliable estimates of past biomass (*13*). But the great numbers of mastodon, mammoth, extinct horse, camel, and bovid bones found in late-glacial sediments hardly suggest scarcity. Evidence that the Late Pleistocene megafauna was declining in numbers and diversity before 12,000 years ago, as Kurtén found in Late Paleolithic sites of the Old World (*14*), is lacking in the New World (*11*).

America's First Population Explosion

The *minimum* growth rate required to attain the estimated (A.D. 1500) population of the New World is negligible, 0.1 percent annually. Slow, imperceptible growth is what demographers are prone to project into the Paleolithic (*15*). They have no choice. Neither bones nor artifacts will reveal instantaneous rates of change. A century of maximum growth, followed by a year of massive mortality, would escape detection by archeologists.

It seems likely that, when entering a new and favorable habitat, any human population, whatever its economic base, would unavoidably explode, in the sense of Deevey [see (*15*)], with a force that exceeded ordinary restraint. The environment of the New World should have been particularly favorable. The hunters who conquered the frozen tundra of eastern Siberia and western Alaska must have been delighted when they first detected milder climates as their route turned southward. Predation loss seems improbable (*11*). More important, the major hominid diseases endemic to the Old World tropics were unknown in the New World (*16*). Hunting accidents undoubtedly occurred, but presumably less often when New World elephants were at bay than in the case of the more wary and experienced mammoths of Eurasia.

When they reached the American heartland, the Stone Age hunters may have multiplied as rapidly as 3.4 percent annually, the rate Birdsell (*17*) reported for the settlement of Pitcairn Island and elsewhere. Anthropologists regard one person per square mile (0.4 person per square kilometer) as maximum for a preagricultural economy on its best hunting grounds. Had such a population density been attained throughout the Americas, it would represent a total population of 10^7 in the 10^7 square miles (2.6×10^7 square kilometers) outside of Canada and other glaciated regions. At a rate of population growth of 3.4 percent annually, or a doubling every 20 years, 340 (17 generations) would be the minimum time needed for a band of 100 invaders to saturate the hemisphere. Even at a rate of 1.4 percent annually, or a doubling every 50 years, saturation would require only 800 years. Presumably a population crash would soon follow the extinction of the megafauna (*4*).

One need not demand that a maximum growth rate was maintained for long, or that the New World Paleo-Indian population ever totaled 10^7 at any one time. Animal invaders expand along an advancing front (*18*). I propose that the human invasion of the Americas proceeded in the manner Caughley [see (*18*)] has reported for exotic mammals spreading through New Zealand (see Fig. 1). A high population density was concentrated only along the periphery. The advance of the hunters was determined partly by the abundance of fresh game within the front and partly by cultural limits to the rate of human migration. In a decade or less, the population of vulnerable large animals on the front would have been severely reduced or entirely obliterated. As the fauna vanished, the front swept on, while any remaining human population would have been driven to seeking new resources.

For the North American midcontinent, I assume the arrival near Edmonton of a band of 100 hunters (Fig. 2). If the average southward movement did not exceed 16 kilometers per year (*19*), 184 years would have been required to develop a population of 61,000, large enough to continue to expand southward at the required rate while maintaining the required frontal density of 0.4 person per square kilometer across an arc 160 kilometers deep. By then the front would have advanced southward 640 kilometers beyond Edmonton (Fig. 2).

Further expansion would be limited not by the maximum rate of population growth but by the assumed cultural limits to migration. A maximum population for North America would be about 600,000, with half that number on the front when it reached the Gulf of Mexico, 3300 kilometers south of Edmonton. The concordant radiocarbon ages Haynes finds among midcontinent man-mammoth sites (*8*) are conformable with the proposed rapid sweep of the hunters. Alternate solutions based on computer simulation are shown in Table 2.

Under the conditions of the model, the front reached Panama at 10,930 years ago. At this point a second slight lag ensued, imposed by the need to develop a broad front into South America after passage of the Panamanian bottleneck (Fig. 3). In this case, a larger initial population seems likely. Within about 130 years, a population growth rate of 3.4 percent annually would again begin to be limited by cultural restraints. By 10,500 years ago, 1000 years after the arrival of the hunters at Edmonton (1200 years after arrival in Alaska), Tierra del Fuego would be within view (Fig. 3).

Table 2. Simulated values for New World population growth.* In example 1, 104 people reached Edmonton 11,500 years ago. They double in numbers every 20 years until limited by their southward migration rate, 16 kilometers per year. Population growth fills a sector of 90° and is concentrated along the arc ("front") through a depth of 160 kilometers. The density on the front is 0.4 person per square kilometer and behind the front is 0.04 person per square kilometer. Example 2 is the same as example 1 except that the population doubles every 30 years. Example 3 is the same as example 1 except that the migration rate is 8 kilometers per year. Example 4 is the same as example 1 except that the migration rate is 25 kilometers per year. Example 5 is the same as example 1 except that the front is 80 kilometers deep. Example 6 is the same as example 1 except that the front is 240 kilometers deep. Example 7 is the same as example 1 except that the front is 0.02 person per square kilometer.

Example	Filling the front		Point at which frontal advance is limited by migration rate			Front reaches the Gulf of Mexico	
	Time (years)	Population	Time (years)	Distance (km)	Population	Time (years)	Population
1	125	8,000	184	393	61,000	345	590,000
2	188	8,000	299	583	102,000	440	590,000
3	125	8,000	159	207	26,000	519	590,000
4	125	8,000	199	583	102,000	294	590,000
5	86	2,800	172	457	40,000	326	435,000
6	149	18,000	193	349	81,000	358	750,000
7	125	8,000	180	368	53,000	344	450,000

* Computer simulations programmed by D. P. Adam.

Modeling Overkill

The impact of the hunters is best visualized if one considers a representative area on their front. If a sizable biomass, say, 50 animal units per square mile, were exposed for 10 years to hunters whose density is one person per square mile on the average, what removal rates would be necessary to reduce the fauna? The fraction of the standing crop of moose available annually to wolves on Isle Royale is 18 percent (*20*); mainly older and young animals are taken. For animals larger than moose, an annual removal rate of 20 percent of the biomass attributable to all predators would very likely be lethal in a few years. Smaller animals (between 50 and 400 kilograms in adult body weight) reproduce at higher rates, but their vulnerability would increase if the hunters preyed less selectively than wolves, taking a higher percentage of adult females.

An annual removal of 30 percent of their biomass should exceed normal replacement by reproduction for all the mammals lost in the Late Pleistocene. If one person in four did all of the hunting, destroying one animal unit (450 kilograms) per week from an animal population on the front averaging 50 animal units per section, he would eliminate 26 percent of the biomass in 1 year. Regions with a higher biomass (more animals), resembling the richest African game parks of today, would not have escaped if the density of hunters rose accordingly.

Provided that each carcass was carefully butchered and dried and all edible portions were ultimately consumed, the minimum caloric requirements for one person per section could have been met by the annual removal of only 5 percent of the assumed 50 animal units per section. But much more wasteful consumption is to be expected, especially if tempting, new prey were easily accessible (*11*). Wheat [see (*3*)] has

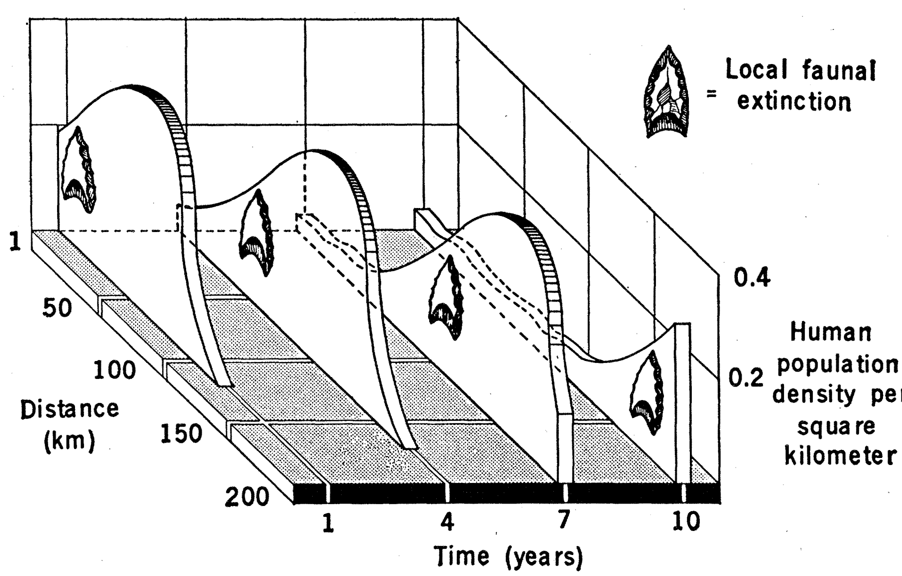


Fig. 1. Passage of the front showing theoretical changes in human population density. At any one point, the big game hunters and the extinct animals coexisted for no more than 10 years. Poor paleontological visibility of kill sites is thus inevitable.

reviewed the historic records of extraordinary meat consumption and occasional extreme waste among the Plains Indians.

Unless one insists on believing that Paleolithic invaders lost enthusiasm for the hunt and rapidly became vegetarians by choice as they moved south from Beringia, or that they knew and practiced a sophisticated, sustained yield harvest of their prey, one would have no difficulty in predicting the swift extermination of the more conspicuous native American large mammals. I do not discount the possibility of disruptive side effects, perhaps caused by the introduction of dogs and the destruction of habitat by man-made fires. But a very large biomass, even the 2.3×10^8 metric tons of domestic animals now ranging the continent, could be overkilled within 1000 years by a human population never exceeding 10^6. We need only assume that a relatively innocent prey was suddenly exposed to a new and thoroughly superior predator, a hunter who preferred killing and persisted in killing animals as long as they were available (*21*).

With the extinction of all but the smaller, solitary, and cryptic species, such as most cervids, it seems likely that a more normal predator-prey relationship would be established. Major cultural changes would begin. Not until the prey populations were extinct would the hunters be forced, by necessity, to learn more botany. Not until then would they need to readapt to the distribution of biomes in America in the manner Fitting (*22*) has proposed.

An explosive model will account for the scarcity of extinct animals associated with Paleo-Indian artifacts in obvious kill sites. The big game hunters achieved high population density only during those few years when their prey was abundant. Elaborate drives or traps were unnecessary.

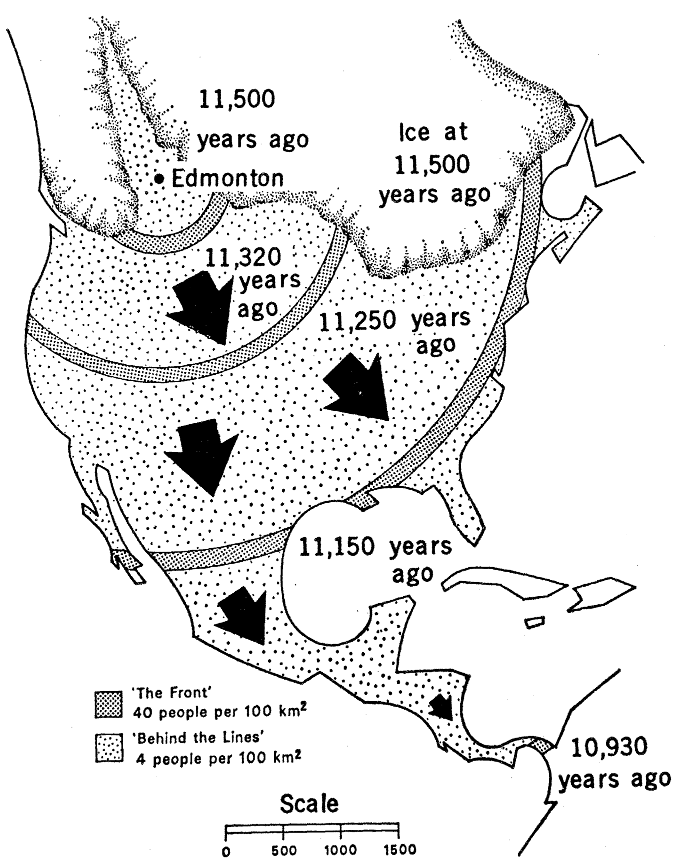
Sudden overkill may explain the absence of cave paintings of extinct animals in the New World and the lack of ivory carvings such as those found in the mammoth hunter camps of the Don Basin. The big game was wiped out before there was an opportunity to portray the extinct species.

Finally, the model overcomes any objections that acceptable radiocarbon dates of around 10,500 years ago on artifacts from the southern tip of South America (*23*) require a crossing of the Bering platform thousands of years earlier (*24*).

As Birdsell (*17*) found in the case of Australia, it appears that prehistorians have overlooked the potential for a population explosion in what ecologists must regard as a uniquely favorable environment—the New World when first discovered. An outstanding difficulty remains, the question of "pre-Paleo-Indians" or "early-early man."

The Hunt for Early-Early Man

The population and overkill model I have proposed predicts that the chronology of extinction is as effective a guide to the timing of human invasion as the oldest artifacts themselves. According to Haynes (*8*), well-dated New World mammoth kill sites cluster tightly around 11,200 years ago. The population growth model presented here requires that the time of human entry into Alaska need be no older than 11,700 years ago to bring the hunters to Arizona by 11,200 years ago and to



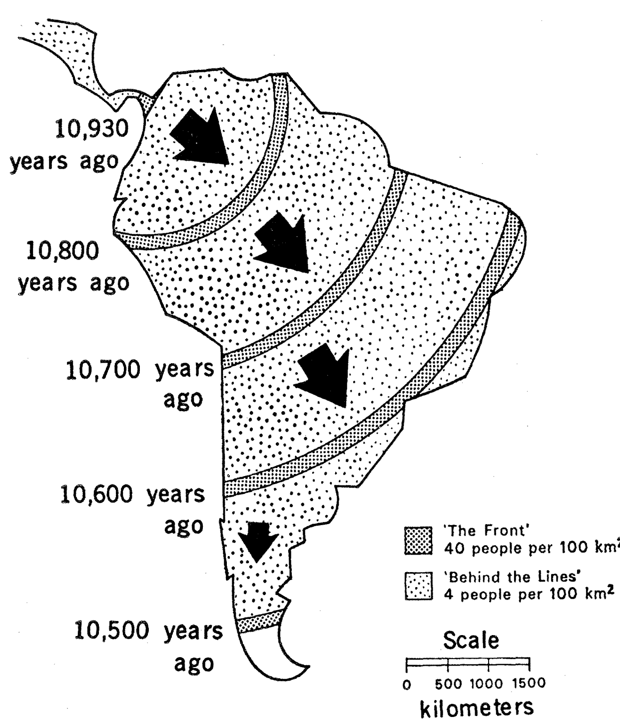


Fig. 2 (left). Sweep of the front through North America. As local extinction occurs, the hunter moves on. Fig. 3 (right). Sweep of the front through South America. Local extinction accompanies passage of the front. (Figures 2 and 3 are not drawn to scale.)

the tip of South America by 10,500 years ago.

A growing number of claims and reviews of sites considered to be at least 13,000 years old or older, including some proposed to be over 20,000 years old, have appeared recently (*25*). The presence of people in the New World long before the big game hunters of 11,200 years ago seems all but conclusively established. Most prehistorians assume that the Americas were occupied by 15,000 years ago (*26*). However, questions of evidence loom.

An ephemeral or scarcely detectable invasion by or before 15,000 years ago implies slow population growth and a low population density. Few would claim that the putative early-early Americans were numerous, and Irwin-Williams [see (*25*)] concluded that they were scarce. A sizable hunt for new evidence of early-early Americans is under way. The more spectacular the claim, the more interest is generated in the announcement (*27*).

The nature of death assemblages, the subtleties of rebedding and redeposition, the uncertainty in diagnosing artifacts, and, especially, the limitations of various dating methods under ordinary field conditions are certain to generate difficulties even for the most careful investigator. Although replication or the critical verification of an original excavation assumes major significance, it is not often attempted.

In a notable exception, the reexcavation of Tule Springs, Nevada, a well-funded team of geologists, ecologists, and archeologists failed to verify the impressive claim of a 23,000-year-old human occupation (*28*). The oldest evidence of occupation that could be verified at Tule Springs occurred in depositional units considered to be between 11,000 and 13,000 years old (*29*).

Their research material has made behavioral scientists especially sensitive to interpreter and experimenter effects. According to Rosenthal, "Perhaps the greatest contribution of the skeptic, the disbeliever, in any given scientific observation is the likelihood that his anticipation, psychological climate, and even instrumentation may differ enough so that his observation will be a more independent one" (*30*). Site replication established the contemporaneity of ancient man and extinct fauna in the New World (*31*).

Replication is now needed if the early-early man sites are to be regarded seriously. The enthusiastic search and the growing number of claims can be viewed as destructive, not supportive, of the early-early man theory. At this point, the more unreplicated claims that are filed, the more likely that their authors may be victims of an experimenter, or, in this case, excavator, effect.

Begging each claim is an ecological paradox: If *Homo sapiens* was clever enough to master a technology that allowed him to penetrate the Arctic or the marine barriers standing in the way of discovery of the New World, why did he fail to exploit the highly productive ecosystem he found in warmer parts of this hemisphere? Why did he fail to leave a trail of evidence at least as obvious as the Mousterian, Gravettian, Solutrean, and other Middle and Upper Paleolithic cultures so abundant in Europe? My questions simply rephrase an objection voiced long ago by Hrdlička and revised by Graham and Heizer (*31*).

For the present, American archeologists can rest assured that ecological principles are not violated by evidence at the known validated sites. A brief moment of big game hunting, not only of mammoth but also of many other species, could have led to megafaunal extinction around 11,000 years ago and to major cultural readaptation in most of the hemisphere afterward. It is not necessary to postulate human invasion by or before 15,000 years ago.

Invasion by a slowly growing and chronically sparse population is not impossible. But it requires major ecological constraints that have yet to be identified in the American environment. Given the biology of the species, I can envision only one circumstance under which an ephemeral discovery of America might have occurred. It is that sometime before 12,000 years ago, the earliest early man came over the Bering Straits without early woman.

Summary

I propose a new scenario for the discovery of America. By analogy with other successful animal invasions, one may assume that the discovery of the New World triggered a human population explosion. The invading hunters attained their highest population density along a front that swept from Canada to the Gulf of Mexico in 350 years, and on to the tip of South America in roughly 1000 years. A sharp drop in human population soon followed as major prey animals declined to extinction.

Possible values for the model include an average frontal depth of 160 kilometers, an average population density of 0.4 person per square kilometer on the front and of 0.04 person per square kilometer behind the front, and an average rate of frontal advance of 16 kilometers per year. For the first two centuries the maximum rate of growth may have equaled the historic maximum of 3.4 percent annually. During the episode of faunal extinctions, the population of North America need not have exceeded 600,000 people at any one time.

The model generates a population sufficiently large to overkill a biomass of Pleistocene large animals averaging 9 metric tons per square kilometer (50 animal units per section) or 2.3×10^8 metric tons in the hemisphere. It requires that on the front one person in four destroy one animal unit (450 kilograms) per week, or 26 percent of the biomass of an average section in 1 year in any one region. Extinction would occur within a decade. There was insufficient time for the fauna to learn defensive behaviors, or for more than a few kill sites to be buried and preserved for the archeologist. Should the model survive future findings, it will mean that the extinction chronology of the Pleistocene megafauna can be used to map the spread of *Homo sapiens* throughout the New World.

References and Notes

1. F. Bordes, *The Old Stone Age* (McGraw-Hill, New York, 1968).
2. P. S. Martin, in *Pleistocene Extinctions, the Search for a Cause*, P. S. Martin and H. E. Wright, Jr., Eds. (Yale Univ. Press, New Haven, Conn., 1967), pp. 87–89.
3. Over the past two decades radiocarbon dates have been published which, if taken at face value, appear to show that mammoths, mastodons, ground sloths, and other common members of the extinct American megafauna lasted into the postglacial. Since my 1967 review (2), the following dates, all younger than 10,000 years old, have appeared: UCLA-1325 (fossil wood below Pleistocene mammal bones); ISGS-17 A,B,C (mastodon ivory and bone); OWU-224 A,B (gyttja with mastodon); A-806 A,C,D; A-874 C; A-876 C; A-195; A-584; A-619; A-536; I-2244; M-1764; M-1765 (bone apatite, acid-soluble organic matter, enamel, and other materials from mammoth bones); UGa-79 (sloth bone). For a complete description of field and laboratory treatment of the samples and for laboratory designations, see *Radiocarbon* **9–13** (1967–1971). In those cases in which stratigraphically associated charcoal dates were available, the bone dates were all significantly younger. They may be suspected of contamination by younger carbon. In another set of especially interesting cases, much younger organic material was found associated with mammoth bones (M-2361, 3310 ± 160 years, conifer cones), a mastodon rib (M-2436, 4470 ± 160 years, conifer log), and sloth dung (UCLA-1069, 2400 ± 60 years; UCLA-1223, 2900 ± 80 years on artifacts). On the basis of other information, the collectors could discount the associations as probably secondary. As long as sample selec-

tion is not foolproof and because bone contamination is not always avoidable, we may expect a steady increase in postglacial dates of the sort which misled me years ago [P. S. Martin, in *Zoogeography*, C. Hubbs, Ed. (Publication No. 51, AAAS, Washington, D.C., 1958), p. 397]. Admittedly, there is no theoretical reason why a herd of mastodons, horses, or ground sloths could not have survived in some small refuge until 8000 or even 4000 years ago. But in the past two decades, concordant stratigraphic, palynological, archeological, and radiocarbon evidence to demonstrate beyond doubt the postglacial survival of an extinct large mammal has been confined to extinct species of *Bison* [see S. T. Shay, *Publ. Minn. Hist. Soc.* (1971); J. B. Wheat, *Sci. Amer.* **216**, 44 (January 1967); *Amer. Antiquity* **37** (part 2) (No. 1) (1972); D. S. Dibble and D. Lorrain, *Tex. Mem. Mus. Misc. Pap. No. 1* (1968)]. No evidence of similar quality has been mustered to show that mammoths, mastodons, or any of the other 29 genera of extinct large mammals of North America were alive 10,000 years ago. The coincidence in time between massive extinction and the first arrival of big game hunters cannot be ignored.

4. M. I. Budyko, *Sov. Geogr. Rev. Transl.* **8** (No. 10), 783 (1967).
5. According to R. F. Flint [*Glacial and Quaternary Geology* (Wiley, New York, 1971), p. 778], "The argument most frequently advanced against the hypothesis of human agency is that in no territory was man sufficiently numerous to destroy the large numbers of animals that became extinct."
6. Apart from postglacial records of extinct species of *Bison*, very few kill sites have been discovered. J. J. Hester [in *Pleistocene Extinctions, the Search for a Cause*, P. S. Martin and H. E. Wright, Jr., Eds. (Yale Univ. Press, New Haven, Conn., 1967), p. 169], A. J. Jellinek (*ibid.*, p. 193), and G. S. Krantz [*Amer. Sci.* **58**, 164 (1970)] have all raised this point as a counterargument to overkill.
7. The North American megafauna that I believe disappeared at the time of the hunters includes the following genera: *Nothrotherium, Megalonyx, Eremotherium*, and *Paramylodon* (ground sloths); *Brachyostracon* and *Boreostracon* (glyptodonts); *Castoroides* (giant beaver); *Hydrochoerus* and *Neochoerus* (extinct capybaras); *Arctodus* and *Tremarctos* (bears); *Smilodon* and *Dinobastis* (saber-tooth cats); *Mammut* (mastodon); *Mammuthus* (mammoth); *Equus* (horse); *Tapirus* (tapir); *Platygonus* and *Mylohyus* (peccaries); *Camelops* and *Tanupolama* (camelids); *Cervalces* and *Sangamona* (cervids); *Capromeryx* and *Tetrameryx* (extinct pronghorns); *Bos* and *Saiga* (Asian antelope); and *Bootherium, Symbos, Euceratherium*, and *Preptoceras* (bovids).
8. C. V. Haynes, in *Pleistocene and Recent Environments of the Central Great Plains*, W. Dort, Jr., and J. K. Jones, Jr., Eds. (University of Kansas Department of Geology Special Publication No. 3, Lawrence, 1971), p. 77.
9. A. Dreimanis [*Ohio J. Sci.* **68**, 257 (1968)] estimates that there are more than 600 mastodon occurrences in northeastern North America. If we suppose that 500 of these were of late-glacial age and assign an equal probability of death, burial, and discovery to each in the time span from 10,500 to 15,500 years ago, then an average of ten may be expected for any given century and one for any decade. I assume that in any one region local extinction was swift. The elephants and their hunters were associated for no more than a decade. Even if the temporal overlap between the elephants and their hunters were as much as 100 years, and if half (five) of the finds represent animals killed by hunters, it is clear that the probability of the field evidence actually being detected and appreciated by the discoverers of the bones is small. Had the hypothetical mastodon kill sites been located on the uplands rather than in bogs or on lake shores, the probability of discovery becomes smaller still. My pessimistic appraisal should not deter those engaged in the search for more kill sites. It should refute the view that extinction by overkill would yield abundant fossil evidence.
10. One animal unit can be used as a standard for paleoecological comparison in the sense range managers have used it for comparing stocking rates under common use. One animal unit equals 1000 pounds (450 kilograms), or approximately the adult weight of one steer, one horse, one cow, four hogs, five sheep, or five deer. Some possible Pleistocene equivalents would be 0.2 mammoth (*Mammuthus columbi*), 0.3 mastodon (*Mastodon americanus*), 0.6 large camel (*Camelops*), one large horse (*Equus occidentalis*), one woodland musk-ox (*Symbos*), three woodland peccaries (*Mylohyus*), or ten cervicaprids (*Tetrameryx*).
11. P. S. Martin, in *Arctic and Alpine Research*, J. Ives and R. Barry, Eds. (Methuen, London, in press).
12. P. F. Wilkinson, in *Models in Archaeology*, D. L. Clarke, Ed. (Methuen, London, 1972).
13. R. D. Guthrie [*Amer. Midl. Natur.* **79**, 346 (1968)] concluded that mammoths constituted 3 to 11 percent of the megafauna in the rich Late Pleistocene deposits near Fairbanks, Alaska. Their size meant that they comprised 20 to 50 percent of the *relative* biomass. But fossil mammal deposits are obviously not randomly distributed. Within a deposit, the rates of bone deposition are unknown and apparently unknowable. There is no prospect of estimating accurately the size of a past population from its fossil bones.
14. B. Kurtén, *Acta Zool. Fenn.* **107**, 1 (1965). The late Würm fossil carnivores of Levant Caves reveal a shrinkage in range, decline in numbers, and reduction in body size.
15. F. Lorimer, in *The Determinants and Consequences of Population Trends* (Population Studies No. 17, United Nations, New York, 1953), pp. 5–20; A. Desmond, *Population Bull.* **18** (No. 1), 1 (February 1962); E. S. Deevey, Jr., *Sci. Amer.* **203**, 195 (September 1960). Deevey proposed an increase of 1.4 times in a 28-year generation, or 1.3 percent annually, as prehistoric man's best effort. C. V. Haynes, [*Sci. Amer.* **214**, 104 (June 1966)] used this value to estimate the population growth of mammoth hunters. Much more rapid growth rates can be assumed.
16. Disease can be discounted. Microbiologists generally regard the Paleolithic as a healthy episode [R. Hare, in *Diseases in Antiquity*, D. Brothwell and A. T. Sandison, Eds. (Thomas, Springfield, Ill., 1967), pp. 115–131]. Their reasons are based less on detailed knowledge of skeletal pathologies or the scarcity of major parasites in prehistoric feces [G. F. Fry and J. G. Moore, *Science* **166**, 1620 (19(R. F. Heizer and L. K. Napton, *ibid.* **165**, 563 (1969)] than on biological inference. Lacking closely related hosts, the New World held no major reservoir of hominid diseases. Cholera and African sleeping sickness never became established. American Indians suffered catastrophic losses in historic time, presumably through lack of prior exposure to Old World diseases such as smallpox and tuberculo [H. F. Dobyns, *Curr. Anthropol.* **7**, 395 (1966)].
17. J. B. Birdsell, *Cold Spring Harbor Symp. Quant. Biol.* **22**, 47 (1957).
18. C. S. Elton, *The Ecology of Invasions by Animals and Plants* (Methuen, London, 1958). Introduced populations of the giant African snail, *Achatina fulica*, attain highest values at the time of establishment, declining rapidly after initial introduction [A. R. Mead, *The Giant African Snail* (Univ. of Chicago Press, Chicago, 1961)]. Exotic large mammals spreading through New Zealand attain peak population densities and maximum reproduction rates at the margin of their range [T. Riney, *Int. Union Conserv. Nature Publ. (n.s.) No. 4* (1964), p. 261; G. Caughley, *Ecology* **51**, 53 (1970)].
19. The proposed migration rate is well within the distance covered by groups of Zulus known to have moved from Natal to Lake Victoria (3000 kilometers) and halfway back in half a century [J. D. Clark, *The Prehistory of Southern Africa* (Penguin Books, Harmondsworth, Middlesex, England, 1959), p. 168].
20. P. A. Jordan, D. B. Botkin, M. L. Wolfe, *Ecology* **52**, 147 (1970). G. B. Schaller [*Natur. Hist.* **81**, 40 (1971)] says Serengeti predators remove roughly 10 percent of the prey biomass.
21. Even when most of their calories come from plants [see R. B. Lee, in *Man the Hunter*, R. B. Lee and I. Devore, Eds. (Aldine, Chicago, 1969)], men of modern nonagricultural tribes devote much time to the hunt. The arctic invaders of America had come through a region notably deficient in edible plants. As long as large mammals were flourishing, there was no need to devise new techniques of harvesting, storing, and preparing less familiar food. None of their artifacts suggests that the first American hunters also stalked the wild herbs, and none of their midden refuse suggests that the succeeding gatherers knew the extinct mammals.
22. J. E. Fitting, *Amer. Antiquity* **33**, 441 (1968).
23. J. B. Bird, *ibid.* **35**, 205 (1970).
24. M. Bates, *Where Winter Never Comes* (Scribner, New York, 1952); R. F. Black, *Arctic Anthropol.* **3**, 7 (1966); H. T. Irwin and H. M. Wormington, *Amer. Antiquity* **34**, 24 (1969).
25. A. L. Bryan, *Curr. Anthropol.* **10**, 339 (1969); unpublished data; C. S. Chard, *Man in Prehistory* (McGraw-Hill, New York, 1969); W. N. Irving, *Arctic Anthropol.* **8**, 68 (1971); C. Irwin-Williams, paper presented at the Conference on Pleistocene Man in Latin America, San Pedro de Atacoma, Chile, 1969; E. Lanning, *World Archaeol.* **2**, 90 (1970); T. F. Lynch, *Occas. Pap. Idaho Univ. State Mus. No. 21* (1967); ——— and K. A. R. Kennedy, *Science* **169**, 1307 (197 R. S. MacNeish, R. Berger, R. Protsch, *ibid.* **168**, 975 (1970); R. S. MacNeish, *Sci. Amer.* **224**, 36 (February 1971); H. Müller-Beck, *Science* **152**, 1191 (1966); P. C. Orr, *Prehistory of Santa Rosa Island* (Santa Barbara Museum of Natural History, Santa Barbara, Calif., 1968); B. E. Raemsch, *Yager Mus. Publ. Anthropol. Bull. No. 1* (1968); A. Stalker, *Amer. Antiquity* **34**, 428 (1969).
26. K. W. Butzer, *Environment and Archaeology: An Ecological Approach to Prehistory* (Aldine-Atherton, Chicago, ed. 2, 1971); J. M. Cruxent, in *Biomedical Challenges Presented by the American Indian* (Pan-American Health Organization Science Publication 165, Washington, D.C., 1968), pp. 11–16; J. E. Fitting, *The Paleo-Indian Occupation of the Holcombe Beach* (Michigan University Museum of Anthropology Anthropological Paper No. 27, Ann Arbor, 1966).
27. One of the boldest claims of great antiquity is that of L. S. B. Leakey, R. De E. Simpson, and T. Clements [*Science* **160**, 1022 (1968)] near Calico Hills, California. Flaked cherts have been reported in fan deposits first considered to be at least 40,000 years old, and later judged to be much older. A study based on a visitation to the quarry in October 1970 by 60 leading American geologists and archeologists sustained the view that the deposits are of great age. It failed to satisfy skeptics that the alleged artifacts were definitely man-made and in a cultural context [C. Behrens, *Sci. News* **99**, 98 (1971)].
28. M. R. Harrington and R. De E. Simpson, *Tule Springs, Nevada, with Other Evidences of Pleistocene Man in North America* (Southwest Museum Paper No. 18, Los Angeles, 1961).
29. C. V. Haynes, in *Pleistocene Studies in Southern Nevada*, H. M. Wormington and D. Ellis, Eds. (Nevada State Museum of Anthropology Paper No. 13, Reno, 1967); R. Shutler, Jr., *Current Anthropol.* **6**, 110 (1965).
30. R. Rosenthal, *Experimenter Effects in Behavioral Research* (Appleton-Century-Crofts, New York, 1966).
31. A. Hrdlička, "Early man in South America" [*Bur. Amer. Ethnol.* **52**, 4 (1912)]; J. A. Graham and R. F. Heizer, *Quaternaria* **9**, 225 (1968).
32. F. Bourliere and M. Hadley, *Annu. Rev. Ecol. Syst.* **1**, 138 (1970).
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