nature communications

Article

https://doi.org/10.1038/s41467-024-52597-8

# The initial spread of peaches across eastern North America was structured by Indigenous communities and ecologies

Received: 5 March 2024

Accepted: 13 September 2024

Published online: 20 September 2024

Check for updates

Jacob Holland-Lulewicz[1], Victor Thompson[2,3], Amanda Roberts Thompson[2], RaeLynn Butler[4], Dario J. Chavez[5], Jay Franklin[6], Turner Hunt[4], Mark Williams[2] & John Worth[7]

We conduct a synthetic archaeological and ethnohistoric dating program to assess the timing and tempo of the spread of peaches, the first Eurasian domesticate to be adopted across Indigenous eastern North America, into the interior American Southeast by Indigenous communities who quickly "Indigenized" the fruit. In doing so, we present what may be the earliest absolute dates for archaeological contexts containing preserved peach pits in what is today the United States in the early to mid-16th century. Along with our broader chronological modeling, these early dates suggest that peaches were likely in the interior prior to permanent Spanish settlement in the American Southeast and that peaches spread independently of interactions with Spanish colonizers. We further argue that that eventual spread of peaches was structured exclusively by Indigenous communities and the ecologies produced through long-term Indigenous land management and land use practices, highlighting and centering the agency of Indigenous societies in the socioecological process of colonization.

Harvested as early as circa 8000 BP in China and domesticated at least by circa 5000 BP in the same region[1], peaches (*Prunus persica*) eventually spread across Eurasia via the Silk Road and on to the Americas during the late 15th and 16th centuries via Spanish colonization, where it became the first Afro-Eurasian domesticate, plant or animal, to be adopted by and spread through Indigenous communities. By the time Europeans were substantively making their way into the interior American Southeast in the middle to late 17th century, dense peach orchards could be found around Indigenous communities, new and greater varieties of the fruit distinct from European strains could be identified, and Indigenous people claimed that peaches were a Native plant species[2–6].

Indeed, peaches continue to play an important and enduring cultural role among the Indigenous Native American societies that the United States government forcibly removed from much of the American Southeast in the 19th century. Peaches played such an important role in Indigenous lifeways that people carried the plants and pits themselves during forced relocation to reservations in Oklahoma from places like Georgia and Alabama[7]. Today, members of the Muscogee (Creek) Nation grow peaches as a heritage or heirloom crop, and the act of caring for these trees remains culturally important.

Historians and archeologists often assume that Spaniards introduced peaches to the American Southeast sometime in the mid-16th century[3,5,8–10], but the timing and geography of their spread remain ambiguous. Despite the uncertainty of these details, the ethnohistoric and archeological records make it clear that peaches were widespread and even naturalized as far north as New York and Pennsylvania by the

[1]Department of Anthropology, The Pennsylvania State University, University Park, United States of America. [2]Laboratory of Archaeology, University of Georgia, Athens, United States of America. [3]Department of Anthropology, University of Georgia, Athens, United States of America. [4]Muscogee (Creek) Nation, Okmulgee, United States of America. [5]Department of Horticulture, University of Georgia, Griffin, United States of America. [6]Logan Simpson Design, Tucson, United States of America. [7]Department of Anthropology, University of West Florida, Pensacola, United States of America.
e-mail: jhlulewicz@psu.edu

late 17th century[4,11]. The rapidity of their propagation has led some to refer to peaches as the first "weed" in the southern colonies of North America[3].

Many studies have been limited in their ability to firmly trace the peach's spread due to a lack of absolute dates and precise chronological modeling. Recent work has done a thorough job of recording many of the locations where peaches are documented between the 16th and 19th centuries (*12 l*). Indeed, this work has done an excellent job of documenting the processes by which new European foodstuffs were incorporated into Indigenous households, communities, and foodways after their initial spread. But, without high-resolution chronological control, the structures of the spread of these plants are difficult to pin down. For instance, Purcell[12] presents a model in which peaches spread through multiple Indigenous pathways into the interior of eastern North America. However, without direct dates on peach pits themselves, or precise, high-resolution dating, as Purcell points out, these models remain suggestions.

Further, while archeologists have commonly cited the peach tree's ability to spontaneously self-germinate, and their propensity to become "naturalized" and spread easily[3,5,8,9], research in plant biology suggests more nuanced biological and ecological characteristics. Peach trees will indeed germinate spontaneously and self-reproduce but cannot spread naturally beyond immediate localities. While they can become naturalized or feral, they require (1) open spaces, as they will not grow where sunlight is limited, and (2) consistent pruning to ensure a healthy and robust fruit crop and to promote the overall positive health of the organism. As such, human intervention is a necessity for any sort of extensive and rapid spread of peaches across a landscape. In this sense, misinterpreted biological characteristics of the peach plant have been far more central in archeological narratives that claim to explain the spread of this new domesticate and thus indirectly downplay the role of Indigenous peoples and communities in this proliferation, as if the Spanish colonizers released peaches and the fruit diffused on its own accord.

A major component of the processes that would have shaped the timing and geography of the spread of peaches, let alone any new species introduced into a landscape, but that is often not considered by archeologists, are the unique ecological requirements that must have been met for these proliferations to have occurred. In this case, given the specific ecological requirements for the spread of peach trees, we argue that their rapid movement across eastern North America could not have happened without the ecological legacies of long-term Indigenous landscape use and management. More specifically, we argue that while the nature of Indigenous sociopolitics allowed the rapid movement of peach seeds through dense, and extensive social networks, ecological conditions characterized by deep-time legacies (c. centuries if not millennia) of land clearing practices (for agricultural fields, for the maintenance of forest and grassland health, for fuel and firewood, and for Indigenous towns) created the perfect environments for the successful anthropogenic proliferation of peach trees. Without ecological alterations by Indigenous societies, the specific structures and character of their social networks, or the historical circumstances of their interactions with Spanish colonizers, peach trees would not have spread where nor when the archeological and historical records indicate.

Extensive Indigenous social networks combined with anthropogenically conditioned ecologies (e.g., long-term legacies of human settlement and land-clearing) would have been the main factors driving the spread of peaches. In this regard, it was the explicit and purposeful decisions, actions, networks, ecologies, and histories of Indigenous communities in the American Southeast that underwrote the initial spread of the first Eurasian plant domesticate into the North American interior. We argue that the integration of peaches into Indigenous food systems and lifeways is best understood along three dimensions: historical, sociopolitical, and ecological and that the specific details and character of the spread of peaches can yield critical insight into questions of Indigenous-colonizer dynamics (historical), the scale and structure of Indigenous networks across the American Southeast at the time of colonization (sociopolitical), and the ecological contexts of the widespread introduction of a new plant species (ecological).

Tracking the complex spread of this introduced species in such a dynamic way allows us to challenge flat or unidirectional narratives of colonial impacts on Indigenous societies. Such narratives often define initial Indigenous-colonizer interactions as a singular event, from which European materials spread unconstrained and homogenously across an undifferentiated landscape of Indigenous peoples willing to "catch" any new European things that flowed through their networks. Instead, we argue that these "flows" were very much constrained along a few axes, entangled with one another in complex, historically and ecologically contingent ways. Thinking about the spread of peaches in this way serves to highlight the complexities and heterogeneity of the process of European colonization in North America while centering the agential role of Indigenous communities in facilitating associated socioecological transformations.

We demonstrate via direct Accelerator Mass Spectrometry (AMS) radiocarbon dating of peach pits, a synthesis of known peach pits from archeological sites, and historic accounts (Fig. 1A) that (1) there was a substantial lag between initial Spanish contact and Indigenous adoption of the peach, that (2) once Indigenous communities did begin to adopt the peach, they spread rapidly across the region, and that (3) despite this lag, there is evidence of peaches in the interior American Southeast that pre-date permanent Spanish settlement in North America. Indeed, we present as evidence what may be the earliest dated peach-bearing contexts in the interior of eastern North America and argue that the rapid spread of the fruit across the continent was not a function of any inherent biological qualities, but of the unique, anthropogenically modified landscapes and ecologies maintained by Indigenous communities. As such, the results presented here are not important simply because they contribute to understanding the spread of a new domesticate but because they contribute to understanding how this process was a component of the complex socioecological history of European colonialism in the Americas.

## Results

### Indigenous communities did not immediately adopt peaches following initial Spanish contact

Of the 28 archeological sites across the broader American southeast where we could determine that peach pits had been recovered, roughly one-third of them ($n = 9$) are Ancestral Muskogean settlements of the Oconee Valley of north-central Georgia (Fig. 1B), communities that are ancestral to the modern Muscogee (Creek) Nation. Prior to this study, just two peach-bearing sites across the American Southeast had been dated via radiocarbon or AMS dating[13,14]. Because of its full coverage survey, the density of sites yielding peaches, multiple 16th century Spanish expeditions through its area, and archeologically and historically demonstrated connections between the Indigenous communities of the Oconee Valley and those of the Atlantic Coast where Spanish missions were concentrated, the Oconee Valley serves as an ideal representative for investigating the timing of the initial spread of peaches into the interior. From six sites throughout the Oconee Valley, 37 organic samples were submitted for AMS radiocarbon dating (Fig. 1B). These samples included large pieces of carbonized tree wood for wiggle-matching dates across multiple tree rings, carbonized hickory nut, and 13 directly dated carbonized peach pits (Fig. 2). Results from Bayesian chronological modeling indicate that peaches were likely present, and even widespread, across both large and small Indigenous settlements of the Oconee Valley starting at *cal AD 1625-1640* (at the 1-sigma or 68% interval) or *cal AD 1620-1645* (at the 95% interval) (Fig. 2).

At the 95% interval, these dates place the arrival and widespread adoption of peaches into the interior of the American Southeast between c. 107–132 years after the first Spanish contact in the region by Ponce de Leon in 1513 in southern Florida, c. 80–105 years after the first Spanish expedition into the interior (and through the Oconee Valley) by Hernando de Soto between 1539 and 1543, and c. 55–80 years after the settlement of St. Augustine and Santa Elena, the first permanent European settlements in what is today the United States in 1565 and 1566 respectively. As such, these dates post-date all expeditions previous to de Soto along the coasts (e.g., Ayllón in 1521, Narvaez in 1527) and even subsequent expeditions such as De Luna's (1559–1561) and Pardo's (1566–1568) which departed from the South Carolina coastal Spanish town of Santa Elena where peaches have indeed been identified, though none have been found at Pardo's interior outposts.

The dates from the Oconee Valley, compared to the arrival of peaches in neighboring regions further into the interior (Fig. 1C), make these Indigenous communities the first in the interior to actively adopt and propagate peaches, defining a "lag time" of c. 115 years between the first Spanish contact with Indigenous peoples of the region and the eventual adoption of peaches by Indigenous communities, despite multiple interactions between 1513 and the early 17th.

### The eventual adoption of peaches was widespread and rapid

Despite the significant lag between initial contact with Spanish colonizers and the eventual widespread adoption of peaches, once the

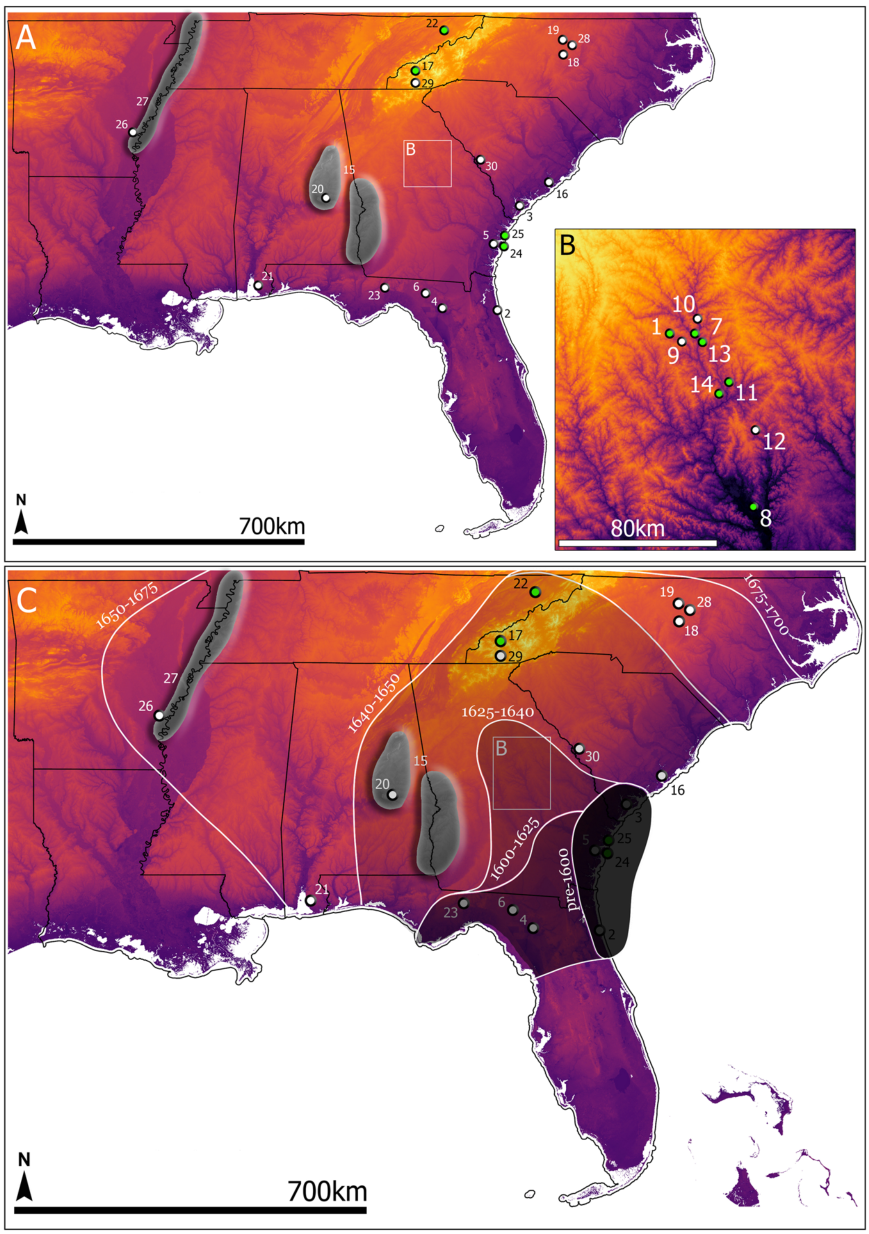


**Fig. 1 | Spatial distribution of AMS, archeological, and ethnohistoric data.** **A** Map of archeological sites pre-dating the 18th century that have yielded charred or preserved peach pits, sites from which peach pits have been directly dated via AMS, and areas or sub-regions where archeological evidence for peaches is limited but can be understood from ethnohistoric accounts. Information on numbered sites is presented in Supplemental Data 1 of the Supplementary Information. **B** Expanded map of Oconee Valley. **C** Hypothesized spread of peaches across the American Southeast. A table of site names and information along with all AMS, archeological, and ethnohistoric data and information for each individual site used to create the dispersal model are all included as Supplemental Data 1. Basemap of elevation data was downloaded from the publicly available USGS National Map (https://www.usgs.gov/the-national-map-data-delivery).

https://doi.org/10.1038/s41467-024-52597-8

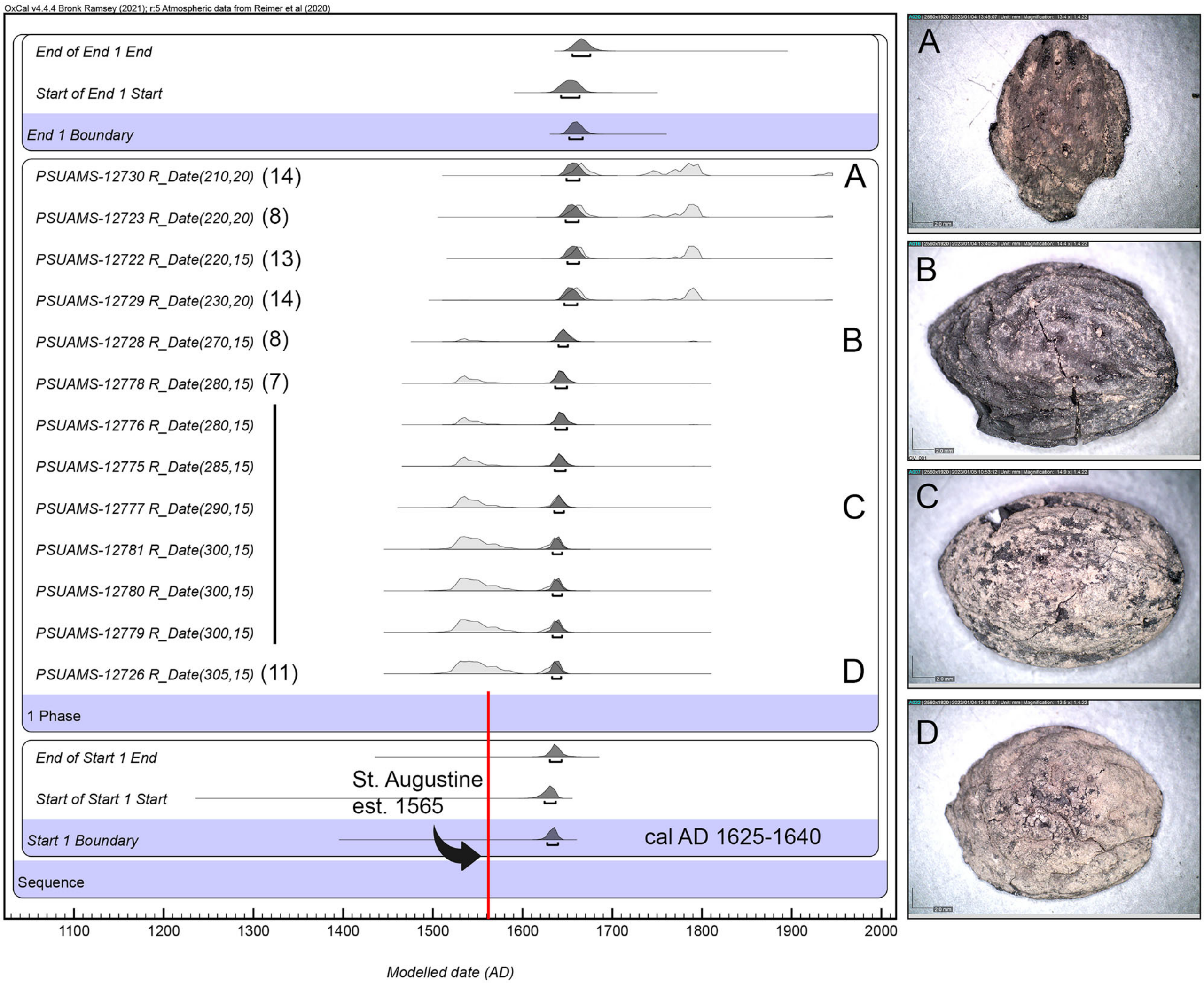


**Fig. 2 | Bayesian chronological model.** Bayesian chronological model of AMS dated peach pits from the Oconee Valley, Georgia (left). This is the primary, simplest model for the timing of peach introduction to the Oconee Valley. All AMS measurements directly on peach pits were incorporated into a single, simple phase model to yield a modeled start date for the arrival of peaches. Individual numbers in parentheses after the sample ID correspond with sites listed in Supplementary Data 1 and presented in Fig. 1A. Alternative models (including expanded, individual site-based models) that yield the same results as the primary model are presented as Supplemental Information. Full methodological details for both the primary and alternative models are included in the methods section below and as Supplementary Information. Photographs of directly dated charred peach pits from archeological sites in the Oconee Valley, Georgia (right). Letters (**A**–**D**) are used to signify which dates in the model are associated with the peach pits in each photograph.

dispersal of peaches began, Indigenous communities moved the plant rapidly across the American Southeast (Fig. 1C), with communities of the Oconee Valley adopting them soon after *cal AD 1625-1640*. Excluding a single site in the Georgia interior discussed in the next section, the earliest dated archeological contexts containing peaches in the American Southeast are those from St. Augustine along the Atlantic Coast in northern Florida, with contexts dating to 1565–1600, and Santa Elena, the first capital of Spanish La Florida, established on the South Carolina coast in 1566 and abandoned by 1587[15].

The first spread is contained locally to Spanish mission sites across La Florida in the early 1600s, spanning parts of modern-day northern Florida and southern Georgia, extending across the northern edge of the Florida peninsula from the Atlantic to the Gulf Coast. Concomitant with this local spread was the adoption of peaches by Indigenous communities of the immediate interior, across the Oconee Valley communities of north-central Georgia between 1625 and 1640. From this interior position, peaches were spread by way of Indigenous networks to the west and to the northeast. By c. 1640–1650, peaches were present in both the Upper and Lower Creek (Muscogee) towns of southwestern Georgia and central and eastern Alabama[16]. At this same time, c. 1650, they were adopted by the Indigenous inhabitants of the town of Alarka in southwestern North Carolina. Similarly, a singularly known pre-18$^{th}$ century peach-bearing site in eastern Tennessee yields a date of c. 1650 (potentially earlier). Peaches finally reached the edge of the region to the west, in Arkansas, by at least 1673, when French explorer Marquette noted a wider variety of peaches in North America than in Europe[17]. At around this same time frame, c. 1670–1680, while they were already present in low numbers, Indigenous communities began to intensify their cultivation of peach trees as the presence of their fruit began to be found more widespread archeologically across North Carolina and the Appalachians[8,18,19]. Indeed, in a 1701 account, peach trees were witnessed growing in the North Carolina Piedmont with "minimal encouragement"[4,20]

While peach trees were proliferating across the mission provinces, they were also doing so across the interior of the American Southeast, reaching as far west as Arkansas in just 30 years after their initial adoption by the Muscogee communities of the Oconee Valley. Importantly, this spread represents not just the acquisition of peaches

 https://doi.org/10.1038/s41467-024-52597-8

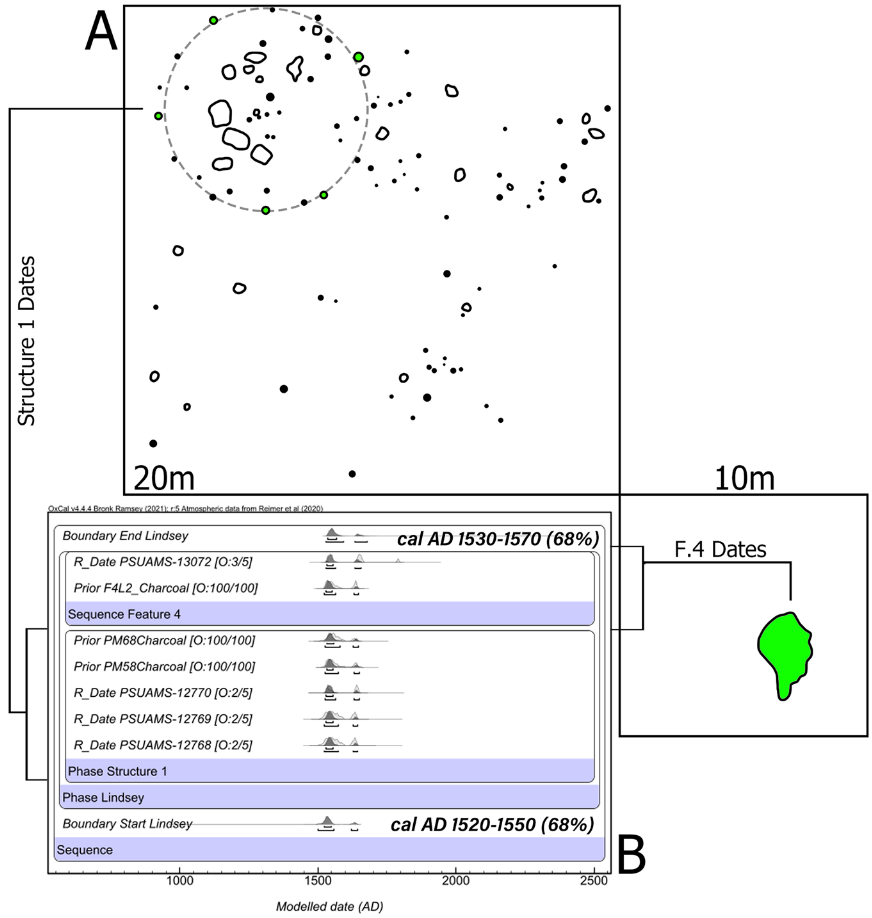


**Fig. 3 | Lindsey site (9MG231) map. A** Map depicting the general layout of the settlement pattern at Lindsey, showing the locations of excavated postholes and samples dated via AMS. **B** Bayesian chronological model of AMS dates from Lindsey.

by Indigenous communities, but the explosion of fruit varieties across the varied environments of the southeast during this time frame, as evidenced by the documented number of peach varieties by European colonizers and by accounts of dense, wild peach tree stands not only in the southeast (e.g., around Charleston, South Carolina in 1682[6]), but as far north as New York[11].

## Peaches are found in the interior prior to permanent Spanish settlement in North America

The Lindsey site is located in the Oconee Valley (Fig. 1B) and represents a small Ancestral Muskogean farmstead of a single household. Recovered from one of the post-holes comprising the round domestic house (Fig. 3A) were two peach pits[21]. In the associated trash pit, archeologists recovered a single blue bead. While it has been estimated that this style of bead may have been introduced in the late 16$^{th}$ century, no previous efforts have attempted to date the site[21]. Ten samples from across the site were thus selected for AMS dating. Two large pieces of charcoal from post-holes associated with the house were used to conduct “wiggle-matching” on AMS dates derived from multiple tree rings within the charcoal sample. Materials from three additional post holes (one of which contained the identified peach pits) were dated, while two dates in stratigraphic sequence were acquired from the associated trash pit. While the contexts containing peach pits were dated, the peach pits were not directly sampled. All dates were incorporated into a Bayesian chronological model (Fig. 3B) outlined in detail in the Methods section below. Three of the seven age estimates were made on charcoal, while the rest of the samples were short-lived species, including maize, hickory nutshell, and walnut shell. While small charcoal samples without the outer rings may sometimes produce erroneously old dates and not correlate with the behavior, activity, or deposit being dated, the resulting age estimates from these samples are in agreement with the dated and modeled ages of the age ranges derived from the short-lived species.

The occupation at Lindsey was potentially short-lived, beginning sometime between *cal AD 1520 and 1550* (68% interval) and ending sometime between *cal AD 1530 and 1570* (68% interval). These date ranges represent what may be the earliest dated archeological contexts containing peaches in what is today the United States. Even if the peach pits were brought to the homestead at the end of its occupation, this would mean that at least some peaches had made it into the interior of the American Southeast before any permanent establishment of Spanish settlements in North America. At a minimum, this would be five years before the establishment of St. Augustine in 1565. At a maximum it would be 30 years before the founding and permanent settlement of St. Augustine. Twenty-five years before the establishment of St. Augustine and permanent Spanish settlement, Hernando de Soto spent 11 days traveling up the Oconee River in 1540, and 45 days moving through the greater surrounding region between northern Florida and the Savannah River along the border of modern-day Georgia and South Carolina[22]. While clearly not the impetus for widespread dispersal of peaches across the region, such encounters like this, or between any number of subsequent Spanish entradas through the interior, could have introduced peach pits (though not likely fresh peaches) to Indigenous communities of the American Southeast long before sustained interactions between colonizers and Indigenous communities were established.

## Discussion

Peaches are virtually absent from Spanish colonial shipping records[23]. While archaeologically, they are found at most Spanish mission sites[15,24–29], documentary evidence for their introduction remains limited, casting ambiguity across the dynamics and temporality of the initial spread of the fruit. It cannot be ruled out that peaches were introduced with the very first voyage to the Americas by Columbus in 1492. Though the status of peaches in the archeological record of the Caribbean is unclear, it remains within the realm of possibility that such an early introduction could have initiated the indirect spread of peaches across widespread Indigenous networks. That said, this does not seem to bear out archeologically. Even if peaches were introduced this early, they would have been in limited numbers; a critical mass of peaches was not met that could yet be detected archeologically or that would have facilitated widespread adoption. Based on the results presented here, the discussion below outlines the historical, sociopolitical, and ecological conditions that facilitated the spread and adoption of peaches by Indigenous communities across the American Southeast circa 140 years after the first arrival of European colonizers.

Importantly, many of the sites dated here, and many like them across the American Southeast, have not previously been subject to robust dating efforts, resulting in either zero directly dated contact-era contexts or sites with limited sample sizes, including some of the sites and models presented in this study. This is primarily because archeologists either rely on material remains or have been thwarted by radiocarbon calibration issues for this time period. As such, future work must continue to design integrated dating programs for 16$^{th}$ and 17$^{th}$ century sites to increase the temporal resolution, and decrease the uncertainty, of our models for processes of colonization.

### Indigenous-colonizer dynamics

While there were numerous Spanish expeditions to the American Southeast following Juan Ponce de Leon's initial 1513 arrival in southwestern Florida, the nature of Spanish presence and interactions with Indigenous communities, between c. 1513 and 1570 was not conducive to the spread and adoption of peaches across the region. Indeed, despite repeated maritime expeditions along the coasts, multiple expeditions into the interior, and a number of established settlements and fortifications during this time, this period, characterized by Worth[30] as primarily military in nature, did not see the diffusion of much European material across the region except for in limited numbers. Indigenous-colonizer interactions during this early period were infrequent and without the intensity that would have driven great material exchange.

While the following period saw less Spanish presence and fewer expeditions into the interior, Spanish settlement in northern Florida and the Georgia Coast became permanent and more intensive as the mission system, led primarily at this time by Franciscans, began to take hold. This period, referred to by Worth[30] as being defined by missionization, saw the establishment of permanent missions, the growth of St. Augustine, and Franciscan missionaries embedded in Indigenous communities across Spanish La Florida. Prior to 1573, when Franciscans took over the reins of Spanish colonial efforts in La Florida, there was no substantive nor sustained interaction between Spanish colonizers and Indigenous communities. Between 1595 and 1605, Franciscan missions were established along the Georgia coast. As demonstrated above, the swift spread of peaches into the interior was not initiated until this new Spanish directive and a shift in the quality and character of colonial efforts from militarization to missionization was completed. The emergence of the mission system was the emergence of true colonial infrastructure that served as the scaffolding for Florida's colonial economy[30]. Importantly, this system did not emerge fully formed but followed decades of military-dominated exploration and experimentation. Within this new mission context, Franciscan friars served essentially as "cultural brokers" within sovereign Indigenous towns[30].

The establishment and provisioning of permanent Spanish missions among Indigenous communities would have facilitated the regular availability of peaches, by way of both the establishment of orchards at mission gardens and through increased and sustained interactions between Spanish missionaries and Indigenous communities. There is, however, a more specific mechanism by which the spread of peaches would have been driven. This specific mechanism, *repartimiento*, was a system of labor taxation in which Indigenous chiefs of sovereign towns would select unmarried young men to go to St. Augustine to provide labor[30,31]. The zenith of this labor draft was in the mid-1600s and would have represented a huge influx of European goods into Indigenous networks (discussed below). *Repartimiento* would have facilitated regularized, indirect connections between Indigenous communities and Spanish economies and would have served to incorporate Spanish communities as nodes within broader Indigenous networks that spanned the American Southeast.

The complexities of colonialism as a process played a key role in mediating and driving the diffusion and distribution of peaches by Indigenous communities. This is an important distinction that should be applied broadly to studies attempting to understand and disentangle Indigenous-colonizer dynamics. Indeed, the establishment of permanent Spanish missions along the Georgia coast by 1605 and the interval necessary for peach orchards to expand and mature around these Spanish settlements, corresponds well with the adoption of peaches by Indigenous communities of the interior by circa AD 1625. While these historical particulars created critical conditions for the spread of peaches, the actual spread to areas beyond direct Spanish influence was mediated by the structure of Indigenous sociopolitical networks.

### Indigenous networks

Socially and politically, the Georgia coast at the time of Spanish contact was split between northern Guale peoples and southern Mocama peoples[32]. Mocama networks and relationships were primarily directed south, into northern Florida, where Spanish presence was also established. Guale networks and political relationships, however, were funneled into the interior of Georgia by way of rivers, though connections to St. Augustine were also strong. Even before the arrival of Spanish colonizers, archeological evidence indicates a long history of established networks and population movements between the Georgia coast and the interior[33]. Historically these relationships are directly documented, including recorded travels specifically of Indigenous inhabitants of the Oconee Valley to the Georgia coast on political business[34]. The interior of Georgia would have been the only region in the interior American Southeast with direct, frequent, and established interactions and networks with Indigenous communities from areas where the Spanish mission system was established, which is clearly supported by the early dating of peaches in the Oconee Valley. Further, once adopted by Indigenous communities of central Georgia, peaches spread rapidly to Indigenous communities widespread across the broader American Southeast. This may suggest the social, political, and economic role of communities in central Georgia as continental brokers between colonizers and the broader American Southeast, though more work on reconstructing these continental scale networks could further define the nature of this potential, critical mediative role. In any case, Gremillion[35], in a study of the correlation between peaches and other European materials, demonstrated that peaches were likely transmitted via the same networks as other European trade goods. Even so, the number of other trade goods is not a good predictor of whether peaches would be found at any site, indicating heterogeneity of access to different kinds of networks by Indigenous communities. Indeed, the topological heterogeneity and complexities of Indigenous networks played a key role in how, when, and where Indigenous communities drove the spread of peaches.

Importantly, this study contributes to our understanding of broad Indigenous sociopolitics and allows us to begin to move beyond many of the highly regional political studies that often characterize the archeology of the American Southeast. Very rarely do archeologists of eastern North America or the Southeast consider the region *en masse* when evaluating sociopolitical organization, choosing instead to focus on individual polities or comparisons between the internal organization of polities. Our study presents a model, albeit one of coarse resolution, for Indigenous sociopolitical networks of the entirety of the southeastern Tribes from the lens of interactions with Spanish colonizers. From a different lens or angle, this broad-scale picture may take on a different form, but in our case, we demonstrate how interactions with European and European-introduced materials took the form of a dendritic tree of interlocking and widespread social networks. More specifically, we demonstrate the long-term, enduring role of the Oconee Valley communities of central Georgia in brokering interactions with the European inhabitants of Spanish La Florida. From this vantage point, we interpret these Oconee Valley communities as the "trunk" of broader social networks from which dense "branches" of network interactions and relationships fan outwards into the interior of the American Southeast and eastern North America.

Even so, the demonstrated heterogeneity of the spread of different kinds of European goods lends insight into the heterogeneity of Indigenous sociopolitical relationships. Just as we argue that we cannot assume a homogenous transfer of European items into and across Indigenous communities, we also have to recognize the heterogeneity and complexities of relationships between Indigenous societies themselves. These nuanced, complex social and political relationships between Indigenous communities, polities, and families would have been rooted in centuries, if not millennia, of social and political histories, machinations, relationships, and tensions, resulting in a heterogeneous landscape of mosaiced relationships and networks. Our studies contribute to the broader discussion of the role of network histories among Indigenous communities in structuring and shaping the complex ways that sociopolitical relationships facilitate certain kinds of interactions and the conditional spread of resources, whether material, immaterial, or otherwise.

### The Ecology of Peach introduction

Archeologists and historians alike have noted the apparent "weedy" spread of peaches across eastern North America[6,10]. Others have made the argument that certain biological characteristics of peach trees contributed to their spread and adoption, including such features as spontaneous germination and their low-maintenance nature, requiring little in the way of husbandry[8,9,13,36]. Gremillion[8,36] has argued that these ecological characteristics, combined with Indigenous experience managing forests and other native fruit trees, would have facilitated a seamless incorporation of peach trees into existing Indigenous "orchards," or at the least into existing Indigenous labor patterns associated with these arboreal foodways.

Peaches are indeed self-pollinating[37] and can proceed from germination to fruit-bearing tree quickly, within just 2-3 years[38]. They prefer ample amounts of water but require well-drained soils[39]. Inundation of root systems by water for as little as 48 hours can lead to the death of the organism; in fact, peach trees are considered to be one of the most sensitive fruit species to waterlogging[39]. Beyond requiring these general conditions, peach trees require substantial sunlight. As such, peaches will not spread into existing forested areas where dense canopies restrict access to sunlight. Maxing out at 15–20 ft in height, peach trees will not compete with dense forest stands and will instead spread most readily into open and disturbed spaces[38,40–42].

Clearings around Indigenous towns and the maintenance of agricultural field systems across well-drained landscapes with fertile soils would have created key components of local ecologies, driving the patchy, mosaic, and disturbed character of these landscapes that would have served as prime environments to grow peach trees[20]. In fact, early English settlers in the 18$^{th}$ century noted the density of peach stands around abandoned Indigenous towns but remarked at the absence of these trees in forested areas[4]. These ecological constraints mean that peaches will not spread naturally into and across forested areas. As such, the rapid spread of peaches up the eastern seaboard to New York and Pennsylvania, and west across to Arkansas would have necessitated anthropogenic intervention, as peaches are not biologically or ecologically equipped to spread beyond specific localities. Birds, deer, and squirrels, while consumers of the fleshy fruit, are likely not prime movers of the peach pits themselves[43], mostly leaving them behind, though small rodents have been documented to collect the seeds of different *Prunus* species elsewhere[44].

Finally, while multiple accounts note "naturalized" stands of peaches, and while natural or "feral" populations of peaches continue to thrive in regions across the globe[11,37,45], production of edible, substantial fruit requires human intervention and maintenance. A healthy peach crop requires pruning to facilitate substantial access to sunlight. Without pruning, the increased density of the canopy will lead to the death of both root systems and even lower branches[46]. Pruning thus opens the canopy to increase the health of the organism. In addition to pruning, the manual thinning of the fruit is required to produce well-sized peaches of a healthy crop[33]. Finally, consistent with ethnohistoric and historic accounts of peach varieties, the ease by which traits can segregate does indeed create incredible variability. While such segregation can occur naturally, these biological characteristics also make artificial selection for traits by people both an easy and rapid process.

With these understandings of the ecological requirements for successful peach tree propagation and proliferation, this study paves the way for future research to more deeply explore not only the relationships between historical ecologies and the spread of new plant species and foodstuffs but also, more broadly, the nature and scale of Indigenous land management and land use histories and practices across the American southeast. What were the specific practices undertaken by Indigenous communities that altered landscape ecologies at scale (whether intentionally or unintentionally)? To what scale were ecologies altered by millennia of Indigenous habitation and landscape use? And, importantly, what are the ecological legacies of these Indigenous histories that shape modern ecologies?

In contrast to narratives of peaches as "weeds," their spread would have been highly constrained and facilitated by anthropogenic factors. From the structure of Indigenous networks to the long-term ecological legacies of anthropogenic land use and modification, the spread of peaches was primarily driven by anthropogenic ecologies and conditions. Combined with the historical process of colonialism and the broad topologies of social networks, the spread of peaches across the American Southeast was fundamentally a complex, multifaceted socioecological process driven primarily by the agency, decisions, and knowledge of Indigenous peoples and communities. Despite the introduction by European colonizers, it was the long-term legacies of Indigenous histories and the immediate expressions of Indigenous agency that facilitated the spread of peaches across the American Southeast and solidified its status as a cultural icon today.

## Methods

### Ethics & inclusion statement

All proper consultations and permissions were acquired from relevant descendant communities to undertake this work and to ensure that the study does not cause risk to these communities. Through the University of Georgia's Laboratory of Archeology, consultations were completed with appropriate, relevant, federally recognized Tribal Nations whose ancestry can be linked to the lands and sites leveraged in this study. Two citizens and official representatives of the Muscogee

https://doi.org/10.1038/s41467-024-52597-8

(Creek) Nation are also included as co-authors for their contributions to interpretations and project design.

### Materials

Materials used in this study include archeological information from excavations and specialized analyses of botanical remains, radiocarbon dates of organic materials via accelerator mass spectrometry (AMS), and information gleaned from historical documents and records. These varying domains of data are described in detail in the following sub-sections. Supplementary Data 1 includes a summary of all archeological, chronometric, and historical data consulted and synthesized.

### Archeological and historical data

Archeological data leveraged in this study include information from 28 individual archeological sites and two regional locales. These include 12 sites located in Georgia, 5 sites in North Carolina, 4 sites in Florida, 3 sites in South Carolina, 2 sites in Alabama, 1 site in Tennessee, and 1 site in Arkansas. The two regional locales include (1) the Upper and Lower Creek towns of southwestern Georgia and eastern Alabama and (2) eastern Arkansas. The 28 individual sites represent most of the known instances of preserved peach pits recovered from archeological sites in the American Southeast. It is possible that more peach-bearing sites exist, but (1) the data may be unknown or difficult to access in the "gray" literature of archeological compliance reports (2), the data or results of excavations and analyses may remain unpublished (3), or specialized botanical analyses have not been regularly conducted and thus peach pit identifications may not have made even for sites from which peaches were recovered.

Across these 28 sites, the time frame for peach presence and adoption has been estimated either through (1) direct AMS radiocarbon dating of peach pits, (2) direct AMS radiocarbon dating of other organic materials found in association with peach pits, (3) broad AMS radiocarbon dating of the site as a whole, (4) the chronological placement of diagnostic archeological materials (e.g., ceramic styles or European materials), or (5) historical information related to the settlement's occupation.

The regional locale of Upper and Lower Creek towns was included as a regional entity instead of individual sites because the high-resolution chronological placement of individual towns is currently unavailable. At present, the botanical data can only be placed within a broad temporal range, as internal settlement chronologies have not been reconstructed through direct absolute dating. The regional locale of eastern Arkansas represents a place where no peaches have been recovered at archeological sites, but where historical accounts can be used to establish a terminus post quem for the introduction of peaches (or the latest possible date).

Historical data includes primary accounts by European and American colonizers or travelers. In most cases, references to these accounts in Supplementary Data 1 link to syntheses of the primary literature. These accounts include mostly references to the presence of peach trees in particular areas, sometimes commenting on their character including their densities, specific locations, the environments they were growing in, and the nature of their fruit. Some examples are listed below:

From William Bartram[47] traveling through Georgia and South Carolina:

"…observed whenever we come to any old Indian Settlements, One or more of these high Indian Mounds, made their appearance -surrounded with little groves of Black Walnut, Mulberry[,] Wild Plumb & Chesnut Trees [.] whether these were anciently cultivated by the natives for their fruit I can't say. but the present nations that inhabit these lands seem very fond of all kinds of eatable fruits & Nuts & take great care to cultivate Peaches [,] grapes, Plumbs &c. The Chickasaw & Cherokee Plumbs is a delicious & excellent fruit & some extraordinary fine Peaches have in their Towns[.]. this is a description of when he traveled through Piedmont."

From Jonathan Dickinson's[48] journal relating his accounts along the Atlantic coast from Florida to South Carolina, in this case specifically referencing St. Augustine:

"The town we saw from one end to the other. It is about three-quarters of a mile in length, not regularly built, the houses not very thick; they had large orchards, in which are plenty of oranges, lemons, pome-citrons, limes, figs, and peaches"

From European communications[49] documented and interpreted by Worth[30]:

"…on Sapelo- very large plantations where we see the ruins of houses burned by the Spaniards themselves We see the Vestiges of a ffort; many great Orange Trees cut down by the Spaniards in septr last There was great plenty of figs peaches; Artechocks onions etc. growing in the priests garden his house had been of Brick & his small Chappell, but all had been burned to Ashes last harvest by themselves; we see the remains & rags of old clothes wch some of our people know to have belonged to the Inhabitants of port Royall."

### Chronometric data

Of the 28 archeological sites from which peach pits have been recovered, 10 of them have been dated via AMS radiocarbon dating (Supplemental Data 1). Seven of these sites were dated as part of this study, six from the Oconee Valley in Georgia and one from the Runion site in eastern Tennessee. Three other sites, Alarka in North Carolina, the Spanish Mission on Sapelo, and Coweeta Creek in North Carolina had been previously dated.

Forty-six new AMS radiocarbon dates from these seven sites are reported in Supplemental Data 2. Organic materials dated include carbonized tree rings from wood samples, carbonized nut fragments, and carbonized peach pits. All materials dated represent either short-lived materials (e.g., nuts or seeds) or individually dated and wiggle-matched rings from large charcoal/wood samples to maximize the precision of dating and the correlation between dated materials and the contexts within which peaches were recovered. For all but one site, all AMS radiocarbon dates were incorporated into site-based Bayesian chronological models. Each model incorporated AMS radiocarbon dates, site stratigraphy, and other chronological and contextual information. These methods are described in detail below. All data and detailed descriptions for each individual site model are included as Supplemental Information. All OxCal code is included as Supplemental Code 1.

### Bayesian chronological modeling: foundations

Bayesian statistics allow us to "analyze new data we have collected about a problem in the context of our existing experiences and knowledge about that problem"[50]. By doing so, we can "arrive at a new understanding of the problem which incorporates existing understandings about the problem and our new data"[50]. To use the associated terminology, new data or observations, can be referred to as likelihoods. Existing experiences and knowledge are referred to as prior beliefs, a priori information, or priors. The resulting understandings we achieve from incorporating our prior beliefs into the analysis of new data are understood to be posterior beliefs. Bayesian statistics are uniquely situated for the analysis of radiocarbon data because of their focus on probabilities. As extensive overviews of Bayesian analysis of radiocarbon dates have been published by experts in the technique (e.g.,[50–55]), only a brief introduction is provided here. The results of "scientific dating are always interpreted contextually," and Bayesian statistics "provide an explicit, quantitative method which can combine raw dates with other prior information included in a model to produce formal statistical date estimates which combine both sets of evidence"[50]. In the following case, radiocarbon determinations represent likelihoods. The association of radiocarbon dates

https://doi.org/10.1038/s41467-024-52597-8

and archeological sites assigned to particular cultural traditions (especially based on particular stone tool technologies) represent our posterior beliefs. The results of the Bayesian modeling efforts represent the posteriors. All models were built using OxCal v 4.4[53,56] and the IntCal20 calibration curve[57].

Adopted by researchers for use in archeological applications over two decades ago (e.g.,[58–63]), Bayes' theorem is often expressed mathematically, with variables representing a set of parameters, observations or measurements, likelihoods, and posterior probabilities[53]. The likelihood is determined by the probability of the data or observations given the set parameters and is proportional to the probability of the parameters themselves. The combination of these two observations/measurements and prior information or beliefs is where the value of Bayesian statistical methods lies, especially in regard to interpreting radiocarbon data.

Because radiocarbon dates are actually measurements of isotopic ratios, in order to be read as proxies for calendrical dates, they must be calibrated against an established calibration curve that reflects fluctuations in atmospheric carbon isotopes over time[57,64]. The process of calibrating a radiocarbon determination, thus results in a probability distribution along which the actual calendrical age of the sample likely lies. The incorporation of prior information about these observations allows for a formal assessment of observations as well as a formal evaluation of the prior assumptions used to interpret the data. Thus, a formalized Bayesian model allows for the simultaneous, quantitative evaluation of both radiocarbon data and our assumptions about the archeological record. Through these efforts, the probability distributions of radiocarbon determinations can be modeled using this prior information and may significantly enhance both the precision and accuracy of chronometric dating by producing modeled posterior probability distributions. Arguably the strongest prior information we have as archeologists are the depositional environments from which radiocarbon data are. More general priors, including culture-historic frameworks, ceramic sequences, settlement patterns, stone tool traditions, and documentary evidence, can also be employed as prior information. When using more generalized prior information, the assumptions employed may serve as a working hypothesis on which the analysis is based[53].

### Bayesian chronological modeling: terminology and commands

A more thorough discussion of the mathematical expressions underlying each of the parameters discussed below is presented by Bronk Ramsey[53]. One of the simplest parameters to impose on a group of radiocarbon dates is their inclusion in a phase. A phase is an unordered group of events. When dates are grouped in a phase, it is assumed that all dates within the group are equally likely to occur anywhere between the start and end boundaries of the phase. No information concerning order is assumed. For the grouping of dates into a phase to serve as an informative parameter (sensu[50]), the phase must be given start and end boundaries. The use of particular kinds of boundaries defines how events (dates) are distributed within the phase. The distributional parameters imposed by particular types of boundaries provide another set of informative parameters that will produce variation in model outputs.

In this study, simple boundary commands were used as well as more complex trapezium boundaries. Whereas the use of the boundary command assumes a uniform distribution of observations within a phase, trapezium boundaries are used to account for the unknown temporalities of start and end events[65]. Trapezium boundaries include two transition parameters that allow for flexibility and "reflect archeological situations in which start and end boundaries could be more realistically expressed by a transition period from a beginning to a peak, and a similar decline towards the end"[66].

Models can also be built by including multiple phases within a model and defining the relationships between those phases. The primary model for the Oconee Valley (Model A) used in the Main Text uses a simple, single phase. For this primary model, all AMS dates made directly on peach pits in the Oconee Valley were grouped into a single phase, and the start boundary for their adoption was modeled. An alternative to this model (Model B), included more prior information. Instead of grouping all peach dates into a single phase for a region, individual sites were modeled that included both peach dates and dates on other materials. These dates were modeled using archeological information like stratigraphy and contextual associations. Modeled peach dates from each individual site model were then saved as priors. All of these modeled peach dates, or priors, were then included in an independent phase using the prior command. This is similar to the primary model (Model A), except the likelihoods included in the phase were not corrected radiocarbon ages, they were modeled priors extracted from individual site models. Start boundaries were then modeled for this 'phase of priors' to determine an overall start boundary for peach introduction into the Oconee Valley. This method has recently been used by others to estimate age ranges for regional archeological traditions and cultures (e.g.,[55,66–68]).

Another set of concepts relevant to the current study that need to be defined are outliers and outlier models. A full review of the kinds of outliers and outlier models that may be applied in Bayesian analyses for archeological applications can be found in Bronk Ramsey[69]. Outlier models are used to "determine whether there are problematic determinations that do not agree with the prior framework"[66]. The model output is thus affected by the down-weighting of particular determinations based on the modeled fit of each outlier. To assess the effects of these model parameters on outputs, the same model frameworks for many of the alternative models were run with and without the application of outlier models.

Charcoal outlier models were used on determinations made on charcoal. More specifically, on charcoal samples that were not subject to wiggle-matching (see below). When multiple samples (e.g., multiple rings) were run from a single charcoal sample, an SSimple outlier model was used, as there is no assumption that the sample to be dated (the individual ring) is older than the event we are interested in dating (the individual ring). We follow this guideline from other published models (e.g., Manning et al. 2018, "Radiocarbon Re-Dating of Contact-Era Iroquoian History in Northeastern North America, Science Advances 4:eaav0280). A General outlier model was applied to each non-charcoal date included in the models. This is especially important as a check on model fit (for all likelihoods), as agreement indices are not useful when employing outlier models. See Bronk Ramsey[69] for the detailed summary and mathematical basis for each of these types of outlier models.

Wiggle-matching was also used to refine individual ages of large charcoal pieces when they were available. Wiggle-matching is so named because it is used to "match" radiocarbon ages to the wiggles of the calibration curve[62,70–72]. The process involves extracting two or more samples from a single piece of charcoal or wood where the number of tree rings between the samples is known. The D_Sequence command in OxCal uses this information to produce a single, refined age for the sample based on the known spacing of AMS-dated samples from the specimen. These resulting ages are then incorporated alongside other dated materials and prior information into site-based chronological models.

### Alternative models and sensitivity

In total, a primary modeling procedure (Model A), an alternative modeling procedure (Model B), and seven individual site models (Models C-H) were used to evaluate the timing and temporality of peach introduction to the interior of Georgia and eastern Tennessee. All models produced comparable results for all outputs in question, indicating the reproducibility of our results, and the robustness of our analyses, given our particular data sets. Each of these nine models is described in detail below, and all OxCal codes used to produce model results can be found after each model description.

To formally probe the sensitivity of our primary models, we used the Difference command to evaluate the formal difference between the start boundaries produced by Model A (primary model) and Model B (alternative model). Both model codes were placed into the same Plot space, and the difference command was used with the overall Start Boundary for Model B as Parameter 1 and the overall Start Boundary for Model A as Parameter 2. The calculated difference at the 68% interval is between 0 and 15 years, while at the 95% interval, the estimated difference could range between −10 and 20 years (Supplementary Fig. 1). As a value of zero is included within the range of the 95% CI, we do not interpret this as a significant difference and that the two models are comparable.

### Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

## Data availability

All data and code used to produce results presented in this text are available in either the main text, supplementary materials, or Zenodo. Source Data for plots presented in Figs. 2 and 3 can be reproduced directly with Supplemental Data 2 and Supplemental Code 1. Data are also archived and available at Zenodo (https://doi.org/10.5281/zenodo.13685025). All collections accessed for this study are curated at the University of Georgia Laboratory of Archeology under the direction of Dr. Amanda Roberts Thompson.

## Code availability

All OxCal code for conducting analyses presented here is included as Supplementary Code 1, archived at both the journal and at a publicly accessible repository described in the Data Availability Statement.

## References


1. Zheng, Y., Crawford, G. & Chen, X. Archaeological evidence for peach (*Prunus persica*) cultivation and domestication in China. *PLOS ONE* **9**, e106595 (2014).
2. Beverly, R. *The History and Present State of Virginia* (University of North Carolina Press, 1947).
3. Crosby, A. *Ecological Imperialism: The Biological Expansion of Europe,* 900–1900 (Cambridge University Press, 2015).
4. Lefler, H. *A New Voyage to Carolina, by John Lawson* (University of North Carolina Press, 1967).
5. Okie, W. *The Georgia Peach: Culture, Agriculture, and Environment in the American South* (Cambridge University Press, 2017).
6. Salley, A. *Narratives of Early Carolina*, 1650–1708 (Charles Scribner's Sons, 1911).
7. Tyner, M. et al. Este Mvskokvlke em vye cvpofuce: The Mvskoke cultural community garden. *Tribal Coll. J. Am. Indian High. Educ.* **30**, 30–34 (2019).
8. Gremillion, K. Adoption of Old World crops and processes of cultural change in the Historic southeast. *Southeast. Archaeol.* **14**, 1–16 (1993).
9. Gremillion, K. "Human Ecology at the Edge of History" in *Between Contacts and Colonies: Archaeological Perspectives on the Protohistoric Southeast* (University of Alabama Press, 2022).
10. Key, J. An environmental history of the Quapaws, 1673-1803. *Ark. Hist. Q.* **79**, 297–316 (2020).
11. Hedrick, U. *The Peaches of New York* (JB Lyon Company, 1917).
12. Purcell, G. *An Analysis of Cherokee Foodways during European Colonization* (University of North Carolina, 2022).
13. Shumate, M. Riggs, L. Kimball, *The Alarka Farmstead site: The Archaeology of a Mid-Seventeenth-Century Cherokee Winter House/Summer House Complex* (National Forests in North Carolina, 2005).
14. Thompson, V., Jefferies, R. & Moore, C. The case for radiocarbon dating and Bayesian analysis in historical archaeology. *Hist. Archaeol.* **53**, 181–192 (2019).
15. Reitz, E., Scarry, C. *Reconstructing Historic Subsistence with an Example from Sixteenth-Century Spanish Florida* (Society for Historical Archaeology, 1985).
16. Bonhage-Freund, M. "Botanical remains" in *Archaeology of the Lower Muskogee Creek Indians, 1715-1836* (University of Alabama Press, 2003).
17. Silver, T. *A New Face on the Countryside: Indians, Colonists, and Slaves in South Atlantic forests*, 1500–1800 (University of Cambridge Press, 1990).
18. Peles, A. "Exploring household foodways in the North Carolina Piedmont, 1450–1710" in *Beyond the Walls: New Perspectives on the Archaeology of Historical Households,* 47–70 (University Press of Florida, 2015).
19. VanDerwarker, A., Marcoux, J. & Hollenbach, K. Farming and foraging at the crossroads: the consequences of Cherokee and European interaction through the late eighteenth century. *Am. Antiq.* **78**, 68–88 (2013).
20. Hammett, J. Ethnohistory of aboriginal landscapes in the southeastern United States. *South. Indian Stud.* **41**, 1–50 (1992).
21. Hatch, J. Williams, M. Humpf, D. King, A. *Archaeological excavations at the Lindsey site, Morgan County, GA*. (LAMAR Institute, 2013).
22. Hudson, C. Smith, M. DePratter, C. The Hernando de Soto expedition: From Apalachee to Chiaha. *Southeastern Archaeology* **3**, 65–77 (1984).
23. South, S. Skowronek, R. Johnson, R. *Spanish artifacts from Santa Elena* (South Carolina Institute of Archaeology and Anthropology, 1988).
24. Marrinan, R. "The lives of friars in Apalachee Province" in *Unearthing the missions of Spanish Florida* (University Press of Florida, 2021).
25. Ruhl, D. Imagining sixteenth and seventeenth century Native American and Hispanic transformations of the Georgia Bight landscape. *Bull. Fla. Mus. Nat. Hist.* **44**, 183–198 (2003).
26. Ruhl, D. *Recent archaeological findings at Mission San Luis de Apalachee*. (Florida Bureau of Archaeological Research, 1999).
27. Ruhl, D. "Customs and traditions in new terrain, sixteenth and seventeenth century archaeobotanical data from La Florida" in *Foraging and farming in the Eastern Woodlands* (University Press of Florida, 1993).
28. Ruhl, D. "Spanish mission paleoethnobotany and culture change: A survey of the archaeobotanical data and some speculations on aboriginal and Spanish agrarian interactions in La Florida" in *Columbian Consequences* (Smithsonian Institution Press, 1990).
29. Scarry, C. Reitz, E. "Herbs, fish, scum, and vermin: Subsistence strategies in sixteenth-century Spanish Florida" in *Columbian Consequences* (Smithsonian Institution Press, 1990).
30. Worth, J. "Missions and colonialism: The view from Spanish Florida, 1513-1763" in *Methods, mounds, and missions: New contributions to Florida archaeology* (University Press of Florida, 2021).
31. Worth, J. "Spanish Florida and the southeastern Indians, 1513-1650" in *Contact, colonialism, and Native communities in the southeastern United States* (University Press of Florida, 2020).
32. Worth, J. *The struggle for the Georgia coast: An 18$^{th}$-century Spanish retrospective on Guale and Mocama* (American Museum of Natural History, 1995).
33. Ritchison, B. Anderson, D. "Vacant quarters and population movements: Legacy data and the investigation of a large-scale population emigration event from the Savannah River valley to the

Georgia coast" in *Following the Mississippian spread: Climate change and migration in the eastern US* (Springer, 2022).
34. Smith, M. *The Archaeology of Aboriginal Culture Change: Depopulation During the Early Historic Period* (University Press of Florida, 1987).
35. Gremillion, K. *Late Prehistoric and Historic period paleoethnobotany of the North Carolina Piedmont* (University of North Carolina, 1989).
36. Gremillion, K. Comparative paleoethnobotany of three Native southeastern communities of the Historic period. *Southeast. Archaeol.* **14**, 1–16 (1995).
37. Bassi, D. Monet, R. "Botany and taxonomy" in *Peach: Botany, Production, and Uses* (CABI, 2008).
38. Money, R. Bassi, D. "Classical genetics and breeding" in *Peach: Botany, Production, and Ises* (CABI, 2008).
39. Johnson, R. "Nutrient and water requirements of peach trees" in *Peach: Botany, Production, and Uses* (CABI, 2008).
40. Huang, H. Cheng, Z. Zhang, Z. Wang, Y. "History of cultivation and trends in China" in *Peach: Botany, Production, and Uses* (CABI, 2008).
41. Loreti, F. Morini, S. "Propagation techniques" in *Peach: Botany, Production, and Uses* (CABI, 2008).
42. Okie, W. Bacon, T. Bassi, D. "Fresh market cultivar development" in *Peach: Botany, Production, and Uses* (CABI, 2008).
43. Spengler, R. Origins of the apple: The role of megafaunal mutualism in the domestication of Malus and Rosaceous trees. *Front. Plant Sci.* **10**, 1–18 (2019).
44. Beck, M. & Vander Wall, S. Seed dispersal by scatter-hoarding rodents in arid environments. *J. Ecol.* **98**, 1300–1309 (2010).
45. Warburton, M. & Bliss, F. Genetic diversity in peach (*Prunus persica L. Batch*) revealed by randomly amplified polymorphic DNA (RAPD) markers and compared to inbreeding coefficients. *J. Am. Soc. Hort. Sci.* **121**, 1012–1019 (1996).
46. Corelli-Grappadelli, L. Morini, S. "Orchard planting systems" in *Peach: Botany, Production, and Uses* (CABI, 2008).
47. Bartram, W. *The travels of William Bartram, 1791* (Francis Harper, 1998).
48. Dickinson, J. *Jonathan Dickinson's Journal* (Florida Classics Library, 1985 [1696]).
49. Dunlop, J. Capt. Dunlop's voyage to the southward, 1687. *The South Carolina Historical and Genealogical Magazine* **30**, 127–133 (1929).
50. Bayliss, A. Bayesian buildings: an introduction for the numerically challenged. *Vernac. Archit.* **38**, 75–86 (2007).
51. Bayliss, A. Quality in Bayesian chronological models in archaeology. *World Archaeol.* **47**, 677–700 (2015).
52. Bayliss, A., Bronk Ramsey, C., Van der Plicht, J. & Whittle, A. Bradshaw and Bayes: towards a timetable for the Neolithic. *Camb. Archaeol. J.* **17**, 1–28 (2007).
53. Bronk Ramsey, C. Bayesian analysis of radiocarbon dates. *Radiocarbon* **51**, 337–360 (2009).
54. Buck, C. Cavanagh, W. Litton, C. *Bayesian approach to interpreting archaeological data* (Wiley, 1996).
55. Whittle, A. Frances, M. Bayliss, A. *Gathering Time: Dating the Early Neolithic Enclosures of Southern Britain and Ireland* (Oxbow Books, 2011).
56. Bronk Ramsey, C. OxCal Program, Version 4.4 (2021).
57. Reimer, P. et al. The intCal20 northern hemisphere Radiocarbon age calibration curve (0–55 cal kBP. *Radiocarbon* **62**, 725–757 (2020).
58. Buck, C., Kenworthy, J., Litton, C. & Smith, A. Combining archaeological and radiocarbon information: a Bayesian approach to calibration. *Antiquity* **65**, 808–821 (1991).
59. Buck, C., Litton, C. & Smith, A. Calibration of radiocarbon results pertaining to related archaeological events. *J. Archaeol. Sci.* **19**, 497–512 (1992).
60. Buck, C., Litton, C. & Scott, E. Making the most of radiocarbon dating: some statistical considerations. *Antiquity* **68**, 252–263 (1994).
61. Christen, J. Summarizing a set of radiocarbon determinations: a robust approach. *Appl. Stat.* **43**, 489–503 (1994).
62. Christen, J. & Litton, C. A Bayesian approach to wiggle-matching. *J. Archaeol. Sci.* **22**, 719–725 (1995).
63. Christen, J., Clymo, R. & Litton, C. A Bayesian approach to the use of 14C dates in the estimation of the age of peat. *Radiocarbon* **37**, 431–441 (1995).
64. Scott, E. & Reimer, P. Calibration introduction. *Radiocarbon* **51**, 283–285 (2009).
65. Lee, S. & Ramsey, C. Bronk Development and application of the trapezoidal model for archaeological chronologies. *Radiocarbon* **54**, 107–122 (2012).
66. Higham et al. The timing and spatiotemporal patterning of Neanderthal disappearance. *Nature* **512**, 306–309 (2014).
67. Becerra-Valdivia, L. & Higham, T. The timing and effect of the earliest human arrivals in North America. *Nature* **584**, 93–97 (2020).
68. Buchannan, B. et al. Bayesian modeling of the Clovis and Folsom radiocarbon records indicates a 200-year multigenerational transition. *Am. Antiquity* **87**, 567–580 (2022).
69. Bronk Ramsey, C. Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon* **51**, 1023–1045 (2009).
70. Bronk Ramsey, C. Development of the radiocarbon calibration program. *Radiocarbon* **43**, 355–363 (2001).
71. Manning, S., Birch, J., Conger, M. & Sanft, S. Resolving time among non-stratified short-duration contexts on a radiocarbon plateau: Possibilities and challenges from the AD 1480-1630 example and northeastern North America. *Radiocarbon* **62**, 1785–1807 (2020).
72. McDonald, L. & Manning, S. A simulation approach to quantify the parameters and limitations of the radiocarbon wiggle-matching dating technique. *Geochronology* **75**, 101423 (2023).

## Acknowledgements
Special thanks to the staff at the Laboratory of Archeology at the University of Georgia for facilitating access to curated collections. Funding was provided for AMS dates by the Institute of Energy and the Environment at The Pennsylvania State University.

## Author contributions
Conceptualization: J.H. Methodology: J.H. Investigation: J.H., R.B., D.J.C., J.F., T.H., A.R.T., V.T., M.W., and J.W. Visualization: J.H. Funding acquisition: J.H. Writing – original draft: J.H. Writing – review & editing: R.B., D.J.C., J.F., T.H., A.R.T., V.T., M.W., J.W.

## Competing interests
The authors declare no competing interests.

## Additional information
**Supplementary information** The online version contains supplementary material available at https://doi.org/10.1038/s41467-024-52597-8.

**Correspondence** and requests for materials should be addressed to Jacob Holland-Lulewicz.

**Peer review information** *Nature Communications* thanks Christopher Rodning and the other anonymous reviewer(s) for their contribution to the peer review of this work. A peer review file is available.