Palaeoethnobotanical Contributions to Human-Environment Interaction

Gary W. Crawford

1 Introduction

I could easily have become a botanist or ecologist when I was a student, but my interests also included human behaviour and our ancient past. Palaeoethnobotany provided the context for me to explore issues that connected people to plants through time. The best definition of palaeoethnobotany as I practice it is "the analysis and interpretation of the direct interrelationships between humans and plants for whatever purpose as manifested in the archaeological record" (Ford 1979). Lately the definitions of palaeoethnobotany and archaeobotany have become blurred. Originally, archaeobotany focussed on the plant remains and the nuances of their identification and assessing traits that distinguish domestication; however, the definition of palaeoethnobotany at least clarifies my background and training. Within environmental archaeology, a subdiscipline that focusses on the interaction of people and the environment, one purpose of palaeoethnobotany is to understand how plant remains can inform this interaction. Palaeoethnobotany addresses many other issues that include social and culinary practices, food preparation and cooking, diet, subsistence practices, agricultural origins, plant domestication, and crop dispersal (Hastorf 1999; Sayre and Bruno 2017; VanDerwarker et al. 2015). These issues are not mutually exclusive and require articulation with environmental issues; however, my chapter does not offer an overview of these topics. Technical aspects such as recovery, preservation, or identification of plant remains have been reviewed elsewhere within the last few years (e.g. VanDerwarker et al. 2015; Marston et al. (or "d'Alpoim Guedes and Warinner") 2014) so are not covered here. Ceren Kabukcu reviews wood charcoal analysis in another chapter in this volume. I focus on the particulars of my experience in East Asia and Eastern North America with issues in

G. W. Crawford (✉)
Department of Anthropology, University of Toronto Mississauga, Mississauga, ON, Canada
e-mail: g.crawford@utoronto.ca

E. Pişkin et al. (eds.), *Environmental Archaeology*, Interdisciplinary Contributions to Archaeology, https://doi.org/10.1007/978-3-319-75082-8_8

palaeoethnobotany as they pertain to human-environment interaction. I emphasize how plants can inform reciprocal interaction between people and the environment and provide some historical background and assess current theoretical perspectives that are mainly, but not exclusively, situated in human ecology. Nearly 20 years ago, I assessed progress in the Northeast region of North America and came to the conclusion that the potential for palaeoethnobotanical research envisioned in the 1960s and early 1970s was finally being realized and that the discipline had finally come of age (Crawford 1999). The same can be said for much of the world today.

2 History and Progress

Palaeoethnobotany is primarily an anthropological field of enquiry that examines the interplay of people and the environment informed by human culture, although a significant component of archaeological plant research focusses on plant remains morphology, domestication, plant distribution, and other specific plant-related issues. My anthropological influences are numerous, but among them the most influential was Richard Yarnell who supervised my doctoral research. He taught both in the anthropology department and in the ecology curriculum at the University of North Carolina. Before I studied with Yarnell, my undergraduate preparation included the fundamentals of anthropology, archaeology, botany, and ecology. However, Yarnell exposed me to novel ways of integrating the complexities of each of these areas, being explicit about reciprocity in human ecology. Vegetation bears the signature of human influence and people in turn developed stable relationships with their anthropogenic landscape, at least periodically and that palaeoethnobotany can inform these issues (Yarnell 1963, 1965, 1982). Their integration did not lie strictly in environmental archaeology; it needed to be in the more inclusive world of human ecology or ecological anthropology. My influences are not only Yarnell but include Geoffrey Dimbleby (1978), Jane Renfrew (1973), Karl Butzer (1975, 1982), Edgar Anderson (1971), Andrew Vayda (1969; Vayda and Mccay 1975), and his students, Fredrik Barth (1956) and Roy Rappaport (1971), to name a few. Eugene Odum's (1963, 1969, 1975, 1983) ecological succession has also informed my archaeological research.

Palynology was prominent in what was probably the first major treatise on people and their relationship to the environment in the Old World (Dimbleby 1978). Jane Renfrew (1973) published the first major English-language synthesis of archaeobotany. The volume provided a synopsis of what we knew about European and Southwest Asian plant remains particularly as they pertained to early agriculture rather than to environmental issues. The palaeoethnobotanical approach that has its beginnings in North America contrasts with that of Dimbleby and Renfrew. New World palaeoethnobotany developed parallel to New World archaeology whose roots were deeply integrated with the ethnographies of indigenous New World peoples (Ford 1979; Willey and Sabloff 1993). Palaeoethnobotany thus developed with strong relationships to anthropological inquiry and the relationships that indigenous people had and have with their environment. Melvin Gilmore, and Volney Jones and his students, who in the early days included Richard Yarnell, were instrumental in developing the foundations of North American palaeoethnobotany. In fact, Volney Jones was an ethnobotanist before he started identifying archaeological plant remains early in career at the University of Michigan (Ford 1978). Richard Yarnell's monograph, *Aboriginal Relationships Between Culture and Plant Life in the Upper Great Lakes Region* (1964), compiled archaeological plant remains data available at the time in the first synthesis of palaeoethnobotany in an explicit interactionist perspective. Two issues Yarnell encouraged us to investigate were manifestly ecological: anthropogenesis and the use of disclimax/early succession vegetation. Following through on these issues where I work in northeastern North America has been hit and miss (Crawford 1999) although elsewhere in North America some attention to these issues has been productive (e.g. Minnis 1978; Hammett 1992, 1997).

Accomplishments related to land use and landscape reconstruction and change are assessed in a comprehensive review of research in palaeoethnobotany (Hastorf 1999) and updated 17 years later (VanDerwarker et al. 2015). The environmental examples in these reviews involve people impacting their environment but not vice versa. The reviews also acknowledge that environment-focused research generally emphasizes plant communities and understanding particular habitats and co-occurrences of plants represented in the archaeological record. Assessing the influence of climate change on agriculture is still a significant research area.

One way to examine trends in palaeoethnobotanical research is to examine specific compilations such as the journal *Vegetation History and Archaeobotany*, the voice of the International Work Group for *Palaeoethnobotany* (emphasis mine) whose focus is not entirely representative of the field, being Quaternary plant ecology, palaeoclimate, and ancient agriculture with an emphasis on the Old World. A review of 94 articles published in *Vegetation History and Archaeobotany* from 2015 through 2017 shows that palynology still dominates (48% of the papers) followed by archaeological seed analyses (33%) (Fig. 1). One paper among the 94 investigates a New World region. The other papers focus on Eurasia and Africa. Most of the palynology and wood charcoal papers are related to environmental reconstruction, but some are addressing anthropogenic forest composition and management (e.g. Dotte-Sarout 2016; López-Sáez et al. 2016). None of the seed-focused papers address human-environment *interaction* as the main point of inquiry, although a few explore anthropogenesis. Exploited habitats are often addressed (e.g. Ramsay and Holum 2015), while another paper examines anthropogenesis as a factor in the abundance of *Canarium schweinfurthii* (Oas et al. 2015). Popular topics among the non-palynology papers are subsistence, plant use, domestication, and type of cultivation practiced. In fact, no explicit archaeological-theoretical perspectives are articulated. Research is materialist or processual, data-driven, and often inductive. Methods are favoured over theoretical perspectives (e.g. Wright 2010) except for issues such as agricultural origins and intensification.

Several edited volumes add to this discussion (Marston et al. (or "d'Alpoim Guedes and Warinner") 2014; Madella et al. 2014). Four chapters of 14 in Madella

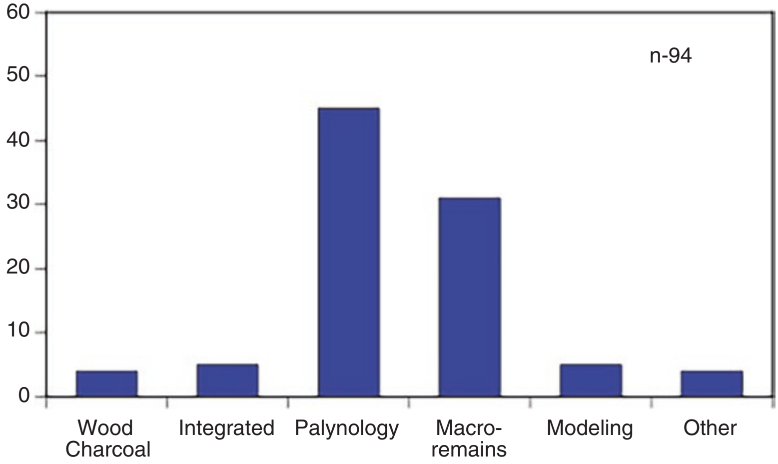

Fig. 1 Percentage of articles in six categories published in *Vegetation History and Archaeobotany* (2015–2017)

et al. (2014) are case studies in "archaeobotany and vegetation history". Two of these chapters are concerned explicitly with ecology: Miller's chapter (2014) explores the interaction of people, plants, and climate, while Riehl (2014) explores whether archaeological plant remains have ecological meaning beyond being weeds. Marston et al. (or "d'Alpoim Guedes and Warinner") (2014) include three chapters that emphasize plants in environmental archaeology (Smith 2014; Gremillion 2014; Messner and Stinchcomb 2014). Recurring themes in both volumes are methodology and subsistence.

Theory in palaeoethnobotany and archaeobotany involves a wide range of issues and topics, but ecology-related theoretical perspectives are not necessarily a dominant focus when we consider journals and edited books over the last 3–5 years. Human ecology is providing the richest body of theory relevant to insights on human-environment interaction derived from ancient plant studies (e.g. Smith 2014; Gremillion 2014; Crawford 2014; Zeder 2016). Current foci are human behavioural ecology (HBE), anthropogenesis, historical ecology, and niche construction theory. Nagaoka and Wolverton (2016) go even further, suggesting that any archaeological research involving human-environment interactions in the past can find an intellectual home in the broad discipline of ethnobiology.

3 Human Ecology

Establishing the ecological context is essential whether we are investigating plant domestication, agricultural origins and intensification, resilience of particular human adaptations in the past, or other related issues. Palaeoethnobotany does not have its own unifying theory (Ford 1979); however, the principles of human ecology and ecological models and methods provide relevant contexts within which the interrelationships between humans and plants in the past may be framed. Determinism is the bane of causality in archaeological explanations (e.g. Hodder and Hutson 2003). Palaeoethnobotany is not immune to deterministic explanations either. Diffusion, climate change, and/or demography may, of course, be part of the equation, but we should not force-fit data to such influences. Doing so is agenda driven, not hypothesis testing. Argumentation becomes circular, and alternative models are usually ignored because these factors are assumed to be the only possible explanations. In many cases, climate change is not the underlying cause of environment change; anthropogenic impacts such as soil salinification resulting from irrigation are usually more significant (e.g. Jacobsen and Adams 1958; Redman 1999). Another view holds that climate change and its environmental impact may have had a significant impact on human lifeways (Messner and Stinchcomb 2014). Human ecology broadens the discourse to conceptualize human culture in part as a result of interaction with physical and biological variables and involves diverse research at different scales (Lopes and Begossi 2009).

Andrew Vayda's vision of human ecology came to focus on contextualizing issues through an open and flexible research agenda (McCay 2008). Vayda proposed that it was best to start with a problematic situation and then examine who does what and to what effect. The data are contextualized through time in order to understand the consequences of human actions. The methodology is problem driven with a clear reference to historical analysis and proximate causation. In other words, the specifics are important. Palaeoethnobotanical data are quite specific and without doubt lend themselves to historical analysis. Dimbleby (1978) was well aware that plants form a significant background for human life and recognized the role human populations played in vegetation history. The role anthropogenic fire played in rolling back succession and creating specific vegetation particularly interested him; however, unlike my own research that focusses on charred seeds and fruit, pollen provided the data for his analysis. Dimbleby clearly understood that anthropogenic influences were discernable even before modern humans evolved.

Disclimax/early succession vegetation feeds into our human ecological approach because it engages the concepts of ecological succession, disequilibrium, and biodiversity. Climax or late succession forests, for example, are old seres that have maximized standing biomass (Odum 1969). Young seres are characterized by short-lived organisms and high net reproduction rates while communities reassemble (Odum 1969; Letcher et al. 2015). This translates to high rates of seed, fruit, and herbaceous plant production. Any form of disturbance leading to disequilibrium transforms vegetation to an early successional stage. Fauna also mirror the changes in vegetation so an understanding of ecological succession permits the prediction of animal demography and biodiversity. Plant assemblages from archaeological sites thus provide insight into actions taken by people to impact biodiversity and ecosystem resilience and production. Agriculture, for example, is a form of ecosystem in which people have created particular forms of plant biodiversity and productivity that require significant human intervention through the life span of the organisms that are involved (Rindos 1984). Community structure is, therefore, not simply determined by climate and soil. Disturbance plays an important role in plant community structure. In fact most ecosystems are in some state of recovery from their last disturbance (Reice 1994). Archaeological plant remains provide an important window into the equilibrium state of local ecosystems.

Ecological resilience refers to the degree of disturbance that an ecosystem can withstand without changing its structure and maintenance processes (Gunderson 2000). An ecosystem may have several equilibrium states, usually resulting from human-induced state changes. People can change nutrient levels, species composition, soil composition, and so on relatively quickly. Whether different equilibrium states exist in the absence of human activities is open to question (Gunderson 2000), but in archaeological research, humans are part of the equation, so our issues involve human presence. Activities such as agriculture and urban development can have long-term impacts on the ability of ecosystems to return to their previous state. Transplanting, cutting, and anthropogenic fire may affect the resilience of ecosystems over shorter timescales. Resilience theory in archaeology acknowledges that relationships between people and the environment may be stable or changing and that the time depth offered by archaeology can document a diverse range of interactions (Redman 2005). A key point in archaeological resilience theory is derived from ecological resilience: many equilibria and cultural systems are possible (Redman 2005; Redman and Kinzing 2003). Archaeological plant remains can contribute to the ecosystem resilience discourse because of their potential to provide deep historical depth.

Three theoretical approaches to plant-human interaction offer productive avenues of enquiry in addition to resilience theory: niche construction, diet breadth/optimal foraging, and historical ecology. A few palaeoethnobotanists have begun to embrace the niche concept. The first use of the concept in anthropology appears to have been in 1956. Barth (1956), using a case study from Swat, Pakistan, defined a niche as the place of a group in its total environment, its relationship to resources and competitors. Separate ethnic groups, although living in the same region, occupied separate niches. In other words, a niche is defined with respect to an occupant. This relativist niche contrasts with the concept of habitat that is defined by a set of environmental conditions but not by how the organism is feeding, competing, or otherwise behaving. Without the organism, the relative niche effectively does not exist. Of course, habitat and niche overlap but they are not identical. Early ecological succession, for example, may be characterized as an important "regeneration niche" (Letcher et al. 2015). Niche construction refers to organisms actively modifying, creating, and interacting with their habitat and with other organisms. In the plant kingdom, for example, some plants such as barley and black walnut have allelopathic effects, that is, they chemically inhibit competition from other plants or resist pathogens (Heisey 1997; Liu and Lovett 1993). Niche construction or ecological engineering (Odling-Smee et al. 2003) is a broader concept than anthropogenesis although the plant signals in the archaeological record are the same. Palaeoethnobotanists are able to discern ecological engineering by considering how ethnohistorically or ethnographically documented activities such as purposeful expansion of habitats, changing soil conditions by churning mud, transplantation, arboreal resource management through selective culling, burning, and sowing wild seed to increase or insure the abundance of specific early succession plant taxa (Smith 2014).

Human behavioural ecology (HBE) is a neo-Darwinist perspective that applies evolutionary ecology to human behaviour (Winterhalder and Smith 2000). It applies mathematical modelling to explain an adaptive problem (Winterhalder and Smith 2000). The most common application is to decisions about resources in the context of diet breadth and risk. Assumptions in HBE include optimization, a cost-benefit measure, and behavioural options (Gremillion 2014; Winterhalder and Smith 2000). Under changing circumstances, according to HBE, people will choose resources in order to optimize yield. Resources evidenced at sites are, therefore, a result of yield optimization decisions. HBE is not a common theoretical perspective in palaeoethnobotany but has made contributions to agricultural origins and understanding cases of changed resource diversity (Gremillion 2014). Understanding which variables contribute to optimization is crucial given that many variables may be unanticipated; ethnographic research indicates that optimality may not be what it is conventionally assumed to be (Gillreath-Brown and Bocinsky 2017). For example, socializing opportunities created while preparing difficult-to-process grain such as emmer wheat, and the taste and texture of emmer wheat are valued over other, less energy optimal wheats (D'Andrea and Haile 2002).

Finally, historical ecology is a form of human ecology that focusses on landscape rather than ecosystems (Balée 2006). It has close epistemological links to niche construction in that anthropogenic landscape transformation and disequilibrium are central to historical ecology. Much of palaeoethnobotany as it pertains to landscape and anthropogenesis is situated in historical ecology. Modelling in archaeobotanical research, for example, is mainly landscape and agriculture oriented (Gillreath-Brown and Bocinsky 2017). In the following examples, I explore how plant remains may contribute to the discussion of human-environment interaction, particularly from the perspectives of historical ecology and niche construction.

4 Japan: Jomon and Satsumon Cultures

The Jomon cultures of Japan represent a diverse set of adaptations that resemble agriculture but defy characterization as farmers (Crawford 2008). The Jomon Period offers an excellent opportunity to explore resilience, historical trajectories, and anthropogenesis/niche construction because of its significant longevity that covers not only the Pleistocene-Holocene boundary but climate and sea level changes throughout much of the Holocene. Jomon material culture and settlement patterns superficially resemble those of agricultural societies, yet intensive production and consumption of grain did not support Jomon cultures. The Jomon developmental trajectory began in the Late Pleistocene much like the predecessors of the Chinese Neolithic did; however, Early Holocene Jomon populations established a different relationship with

Japanese archipelago ecosystems than did the Chinese Neolithic cultures (Crawford 2011a). A valuable historical ecology-focused discussion currently revolves around the extent to which demographic and socioeconomic changes occurred and how resource diversity contributed to resilience and change during the Jomon in northeastern Japan (Habu 2015). Plant remains are direct evidence of resource extraction and use, so provide another dataset with which to test hypotheses of resource diversity and the effects that Jomon people had on these resources. Some scholars characterize the Jomon populations as specifically nonagricultural hunter-gatherers who lived relatively passively in the relatively rich ecosystems of the Japanese islands (e.g. Kobayashi et al. 2004; Imamura 1996) that provided marine and other aquatic resources such as salmon and shellfish as well as deer, chestnut, walnut, acorn, and horse chestnut/buckeye. This interpretation overlooks critical aspects of Jomon-environment relationships. For example, palaeoethnobotanical research indicates that the immediate Jomon environments were not quite "natural" Crawford (2008).

Beginning in the late 1970s, we began a long-term study of plant remains from Jomon sites in northeastern Japan. The charred plant remains recovered by flotation represent a far greater diversity of utilized plants and a more complex ecological setting than the standard model does. I estimate that close to 200 taxa are represented in the plant remains from northeastern Jomon sites (Crawford 1983). A quantitative and contextual analyses of these plant taxa indicate that fewer than 20 of these are common to most Jomon sites and they are found in contexts indicating that the plants were abundantly growing in and around Jomon occupations and recovered in contexts suggesting their utilization (Crawford 1983, 1997). Most of the plants are herbaceous annuals: grasses, several species of *Polygonum* (knotweed) and *Rumex* (sheep sorrel), and *Chenopodium*, possibly *C. ficifolium*. Although we recovered at least 18 types of grasses, only 2 or 3 are common: barnyard grass (*Echinochloa crus-galli*), *Digitaria*, and a type of Triticeae, likely either *Elymus* or *Agropyron*. The latter taxon was found only in one context, at the Yagi site on an activity surface in what would have been a bowl-shaped depression on top of the fill of a collapsed pit house. Barnyard grass has been recovered from nearly every northeastern Japan Jomon site from which we have collected flotation samples. Caryopses of this grass are normally recovered from hearths, floors, pits, and post holes, at least in the Kameda Peninsula. The grain size distribution from the Middle Jomon Usujiri B site is bimodal suggesting that Jomon people were selecting for larger seeded grains. A specimen recovered from the interior surface of the base of a pot is morphologically identical to the domesticated form of broomcorn millet, Japanese millet (*Echinochloa utilis*) (Crawford 2011a).

The knotweed family (Polygonaceae) is represented by at two or three genera: *Polygonum*, *Rumex*, and probably *Persicaria* (smartweed). The most common is Japanese knotweed (*Polygonum cuspidatum*), a perennial plant that has spread throughout much of the northern hemisphere and is a noxious weed. This relationship with people appears to have begun during the Jomon. *Rumex* is found at Early and Middle Jomon sites but is more common or in higher densities in the Middle Jomon. All are early succession taxa, that is, they flourish in disturbed, sunlit habitats. Shrub and tree fruit are also well represented at Jomon sites too. These are primarily *Actinidia*, bramble (*Rubus*), elderberry (*Sambucus*), and *Aralia*. The latter genus has both herbaceous and arboreal taxa in Hokkaido, and both may be represented. These all produce abundantly in well-lit habitats such as clearings and woodland edges. These perennials are late early succession taxa. Two mid-succession taxa relatively common at Jomon sites are sumac and lacquer tree (Noshiro and Sasaki 2014; Crawford 2011a). Their seeds are distributed quite differently from most other taxa. Lacquer production and use began quite early during the Jomon Period in Hokkaido. Both sumac and lacquer tree prefer prolonged, disrupted habitats. Sumac grows in clones, while the lacquer tree, in order to produce enough lacquer for production purposes, needs to be grown in orchards. Other tree fruits evidenced at sites in Hokkaido are Amur corktree (*Phellodendron amurense*), walnut (*Juglans ailantifolia*), and chestnut (*Castanea crenata*). Abundant remains of chestnut don't occur until later periods in Hokkaido, as evidenced at the Late Jomon Seizan site (e.g. Crawford 1983, 1997). Some Jomon contexts in Hokkaido have high densities of nut remains, while many do not. Elsewhere in Japan, aDNA, pollen, and macro-remains indicate that nut management was important in some areas (Noshiro and Sasaki 2014; Sasaki and Noshiro 2004; Sato et al. 2003). Arboreal resource management is an important issue and has been a focus of attention not only in Japan but in the New World (for a summary, see VanDerwarker et al. 2015) and, to some extent, Europe. Understanding the ecology of nut and other arboreal resource productivity is crucial to modelling arboreal resource management and domestication.

Plant remains from Jomon sites are consistent with the interpretation that a diverse mosaic of anthropogenic habitats of varying maturity were in the vicinity of Jomon habitations (Fig. 2). By expanding the area of these mosaics, while maintaining their diversity, anthropogenic resource richness was maintained, and productivity was intensified. The normal ecosystem resilience was impacted by human activities that established a variety of anthropogenic plant communities. Some of these communities would have been inadvertent, while others were purposefully maintained. Barnyard grass and lacquer tree were likely cultivated. Japanese millet and barnyard grass seeds are distinguishable today, and the bimodal distribution of the Middle Jomon barnyard grass seeds from Hokkaido suggest that barnyard grass was responding to its interaction with humans by producing larger seeds. However, because seed size is likely a late trait to evolve during the domestication process, selection for other traits such as the reduction of inflorescence brittleness may have been developing and developing earlier, but because we don't recover rachis segments of barnyard grass, we have no way of knowing. Nevertheless, plant remains from northeastern Jomon sites indicate that the Jomon people were living in a human-modified ecosystem. The local vegetation was significantly anthropogenic, meaning that plant diversity (and terrestrial animal diversity) was relatively high. In central Honshu, soybean (*Glycine max* subsp. *soja*/*G. max* subsp. *max*) and adzuki (*Vigna angularis*) morphologies are consistent with their domestication by 4000 B.P. Comparable examples have not been found outside Japan, so it appears that these plants were domesticated in Japan (Lee and Crawford 2011). Domestication of plants during the Jomon period occurred in anthropogenic contexts and in a

Fig. 2 Environs of the Middle Jomon Usujiri B site in 1977. Many plants growing in the patchy range of early successional vegetation around the site today are found among the charred plant remains recovered from the site

human-mediated vegetation equilibrium that was productive and diverse. This, in turn, facilitated an array of near-complex, Neolithic-like Jomon populations.

The ultimate demise of the Jomon in northeastern Japan was not the result of an ecological failure; instead, it was a complex process that involved interaction with the rapidly developing Japanese society to the southwest (Crawford and Takamiya 1990). The resilient Jomon systems in southwestern Japan were impacted by a significant event: a wave of migrants bringing a Chinese/Korean form of agriculture that included rice, barley, wheat, and millets dramatically altered the lives and landscape of the Jomon. By the end of this new Yayoi period, most of Honshu, Kyushu, and Shikoku became the home of burgeoning farming cultures. Hokkaido Jomon cultures transformed too, but they maintained a distinctive identity that was a continuation of the Jomon, the Epi-Jomon culture. This speaks to their general resilience. After several centuries of relative stability, the Epi-Jomon declined and ceased to exist (Takase 2014). How this happened is unclear. Nevertheless, by the sixth century A.D., this culture no longer existed. If the preceding 10 millennia of Jomon occupation of Hokkaido were involved with the creation and maintenance of anthropogenic habitats, then we might expect to see a return to non-human-mediated ecological resilience. North America, for example, was not a pristine wilderness before European contact (Denevan 1992; Hammett 1992, 1997). Habitual use of certain habitats, burning, and farming had transformed parts of the North America landscape. After European contact populations declined by as much as 90% or more, and the subsequent lack of indigenous ecological maintenance activities resulted in the return of mature ecosystems. A similar process may have happened in Hokkaido.

Epi-Jomon We have intensively flotation-sampled several Epi-Jomon sites (Crawford 1987; D'Andrea 1995). Qualitatively, the plant remains are similar to those of the preceding Jomon plant assemblages. Quantitatively, however, distinctions are clear. The large K-135 site in Sapporo has numerous pits, outdoor hearths, and no evidence of dwellings. The site is stratified, and several occupations are separated by alluvium. Walnut, chestnut, and acorn are relatively common but occur in dense concentrations in some localities but are in low densities in other localities. Many contexts have no nut remains at all. Other perennials include a variety of tree and shrub fruit as well as Japanese knotweeds. One context has a particularly high density of Japanese knotweed indicating that it was of some significance to the inhabitants of the site. Herbaceous plants are not particularly common. However, they are not absent either. The habitats people were exploiting appear to have been ecologically more mature with some representation of early successional plants. No evidence of increased landscape clearing or ecological disruption, trends that we would expect if the Epi-Jomon population was locally increasing at a year-round or near year-round village, has been found. Although the K135 site has a grain of barley (*Hordeum vulgare*) among its plant remains, none of the evidence points to the residents cultivating plants. Barley is probably a component of the well-documented networking between the Tohoku Yayoi and the Epi-Jomon. Plant resources appear to been more targeted than in preceding periods too. In other words, anthropogenesis during the late Epi-Jomon period appears to have been inadvertent or simply a result of periodic human influences and periodic flooding that had a role in plant succession. What caused this human ecological and demographic shift is not known; however, the types and quantities of plant remains are consistent with smaller populations who were no longer impacting the landscape as their ancestors did.

Satsumon Finally, sociopolitical circumstances led to a new form of human-environment interaction. Epi-Jomon populations were replaced by a new culture with a mixed economy of farming, hunting, fishing, and gathering and who were ultimately the ancestors of the Ainu. This new culture is known as the Satsumon. Its origins and development are closely linked to the relationships people in Tohoku had with southwestern Japan. As centralized political authority and related socio-economic institutions developed in the southwestern region, Tohoku cultures developed too but maintained their independence and local identities. One significant development was the establishment of rice, millet, barley, and other crop cultivations in Tohoku. Sometime in the seventh or eighth century A.D., the earliest Satsumon peoples became established in southwestern Hokkaido bringing agriculture with them. They also hunted, fished, and collected plants. This mixed economy established a new human ecology in Hokkaido. Landscape clearance was undertaken not only to create hamlets and villages but to create fields. So far, no evidence of rice paddies has been found in Hokkaido; dry field creation and maintenance were the main concerns. On average about 40% of the plant remains from Satsumon and Tohoku Yayoi sites are rice and other crops. In Hokkaido, the proportion of crops at Satsumon sites is similar although we have found outliers with both low percentages (5%) and high percentages (90%) of crop representation. Few nut remains are found at the sites indicating that woodlands were returning to mature states in which nut trees were not particularly common. Instead, people were investing their ecological management efforts in more specific habitat creation. Many of the grass taxa identified at Jomon sites are found at Satsumon sites, but the grasses are far more diverse and include a wider range of Paniceae tribe grasses, predominantly green foxtail grass (*Setaria viridis* subsp. *viridis*). Contrasting with the earlier Jomon sites, Japanese knotweed is no longer a significant component of the plant assemblages; rather *Polygonum densiflorum* or *Polygonum lapathifolium* is common. This is consistent with the annual cultivation cycle typical of field maintenance. Japanese knotweed was probably still a significant component of the vegetation along forest edges and trails, but because alternative resources were available, people seem not to have included it in their plant-collecting activities. Furthermore, the qualitative and quantitative similarities shared by the Early through Late Jomon and Satsumon assemblages indicate that annual disturbances maintained similar habitats (Crawford 1997). That is, Satsumon and Jomon sites were occupied for lengthy, continuous periods, and plant cultivation was likely practiced by both cultures, although they were not the same type of cultivation. The density of annual plants, particularly weeds, at Satsumon sites is significantly higher than at Jomon sites consistent with the view that Jomon people practiced a smaller scale of cultivation than the Satsumon people.

5 Ontario, Canada: Archaic and Late Woodland

Preceding the establishment of intensive domesticated plant production in Ontario, for example, was a several millennia-long Archaic Period culture. This culture is characterized by the absence of pottery, an emphasis on hunting, fishing, and gathering and a range of landscape investment from seasonal use of particular territories to relatively long-term use of a local area. The McIntyre site on Rice Lake fits the second land use pattern. McIntyre was occupied periodically for several thousand years (Johnston 1984). Contrary to the pervasive perspective of passive human involvement in the local ecosystems, the McIntyre plant remains have signatures of anthropogenesis and a specific cultural niche. Charred butternut shells (*Juglans cinerea*) are in such quantities that they must have been an important resource (Yarnell 1984). Butternut, however, is rare in local forests and, like all nut trees, does not produce much mast in a mature woodland (mature sere). Yarnell (1984) argues for butternut tree management and if this is the case, the Late Archaic McIntyre population had made a significant, long-term investment in a particular form of plant ecology. Other perennial, arboreal taxa requiring open, sunlit areas include hawthorn (*Crataegus* sp.), bramble, sumac (*Rhus typhina*), and grape (*Vitis* sp.). All do well in openings and in edge habitats, particularly in areas that people cleared. In fact, these taxa are common in later agricultural contexts in Ontario. Herbaceous plants are dominated by two taxa: *Chenopodium hybridum* and cleavers (*Galium* sp.). *Chenopodium hybridum* grows well in semi-shaded areas, as do cleavers. Both were found in high densities indicating that they were important to the McIntyre site residents. There is no evidence that any of these plants were cultivated; all the plants recovered from the site except butternut were probably invasive to the habitats people had inadvertently created, and people took advantage of them and may have encouraged them to grow. People were likely aware of the plants in addition to butternut that were responding to their regular use of this location. McIntyre is situated on the shores of Rice Lake so initially fishing may have attracted people to this locale, but the addition of anthropogenic habitats that provided attractive resources ensured that people would return for several millennia. This is consistent with Yarnell's observation that mobile indigenous bands seasonally returned to camps because of the anthropogenic vegetation that was useful to them (Yarnell 1964).

People were living in substantial year-round villages and grew maize, sunflower, squash, and tobacco in Ontario by 1100–1200 A.D. (Late Woodland II period). Common bean was added to the repertoire of crops in the next century (Hart et al. 2002). The diversity of plants recovered from these late Woodland Period sites is significantly greater than in previous periods although the plants represented at Late Archaic sites are still part of the later assemblages (Crawford 2014). Plants had some of the same opportunities in the environment near and inside late Woodland communities that they had in earlier periods. That is, arboreal perennials such as trees, shrubs, and vines from edge and sun-exposed habitats were still important components of the vegetation. Nut trees are not represented to any great extent although this seems to depend on the particular site. Annual, herbaceous plants are recovered in much higher densities after 1200 A.D., and many of these plants were probably field weeds. Examples include American nightshade (*Solanum americanum*), ground cherry (*Physalis* sp.), knotweeds, goosefoot, portulaca (*Portulaca oleracea*), and certain grasses. Strawberry (*Fragaria virginiana*), a fruit almost absent from earlier periods, is recovered in high densities from many contexts so its abundance correlates with agriculture because it thrives in early succession contexts (open and plenty of sunlight). The goosefoot is a different species than the one at McIntyre, that is, not the shade-tolerant species. Although the goosefoots are notoriously difficult to identify to species, the Late Woodland species appears to be a weedy variety of *C. berlandieri*, a species that does well in disturbed, sunny habitats. Most of the grasses are members of the Triticeae and Paniceae.

Berries from shrubs such as bramble (blackberry or raspberry) and blueberry are usually found in high densities at Late Woodland Ontario sites too (Monckton 1992; Ounjian 1998; Crawford and Smith 2003). Bramble seed density is several orders of magnitude higher than at any Jomon or East Asian Neolithic site that I have studied. Not only are their preferred habitats common (well-lit habitats, early- to mid-succession seres), but, given the ubiquity and density of the seeds from these plants, their habitats were extensive and likely maintained by people. Bramble, because it can form dense hedgerows, may have functioned as a barrier. Blueberry production responds well to burning, so Late Woodland peoples probably included fire in their landscape management repertoire. We can't rule out American nightshade, ground cherry, goosefoot, or strawberry cultivation either. A parallel case is made for the Neolithic of the northeastern Iberian Peninsula where the systematic use of tree, shrub, and herbaceous plant fruit is documented and likely interrelated in some way with farming practices (Antolín and Jacomet 2014).

The plant assemblages from Ontario Late Woodland sites reflect an extensive and variable anthropogenic vegetation mosaic that offered a diverse array of plant resources. The relationship between plants and their communities and people during the Late Woodland was more complex than in preceding periods. The extensive clearance that would have been required for the construction and maintenance of Late Woodland villages and their associated fields had far-reaching ecological impacts (Fig. 3). The edge habitats, clearings, and extensive trail systems that joined communities also had an impact on plant communities. These anthropogenic ecosystems were created and maintained for up to two decades, and then villages moved. But that would not have been the end of it. Abandoned village/town locales would have taken decades to reforest and would have continued to be important plant collecting areas. We should not assume that the plants represented in the samples from a particular site represent plants collected only from the immediate vicinity. By the late sixteenth and early seventeenth centuries when Europeans made first contact with indigenous peoples, they described a landscape not that different from

Fig. 3 Reconstruction of the Crawford Lake site near Campbellsville, Ontario. Small-diameter trees were extensively used in order to construct the large, multifamily longhouses. Communities were normally several hectares in area and significantly altered local vegetation

the landscape they were familiar with in France (in the Ontario case). They observed a landscape of fields, orchards, and pastures. The archaeological record is consistent with these observations (Crawford 2014).

A challenge for palaeoethnobotanical research in Ontario is to sort out when and under what circumstances this landscape transformation began. The best evidence resulted from our Princess Point (Late Woodland I Period) project that we developed in the early 1990s (Smith and Crawford 1997). The first indications of a changed relationship between people and the landscape in Ontario became evident when we compared Princess Point settlement locations with the locations of the preceding Middle Woodland sites. Middle Woodland sites are distributed across the landscape, while Princess Point sites are, with a few exceptions, close to major rivers and lakeshores. This contrast is remarkable and required explanation. The recovery of plant remains from selected Princess Point sites combined with geomorphological research provided the answer. Charred maize fragments are present in our sample of Princess Point sites. The majority of Princess Point sites are situated on floodplains or, more accurately, river bars (Walker et al. 1997; Crawford et al. 1998). These river bars never continuously added alluvium through annual flooding. Flooding appears to have been episodic, that is, sometimes alluvium was deposited suddenly, and at other times alluvium accretion was slow in any at all. Princess Point sites along the Grand River are all associated with a palaeosol (Crawford et al. 1998, 2006). The development of this palaeosol correlates with a period of river bar stability, that is, little evidence of regular flooding is apparent during the occupation. If the water was high during the particular spring runoff, water was diverted by channels leaving the occupations that were close to the river relatively dry. These locations appear to have provided the best locations for early maize production, but the location was not simply a stable location with rich soils. It was also an anthropogenic setting. The maize is associated with plant remains more commonly found at the later agricultural sites. Seeds of grasses, chenopod, American nightshade, ground cherry, and purslane, for example, are found in many flotation samples and develop high densities by the end of the Princess Point period (Saunders 2002; Crawford et al. 2006). Bramble, the significant biennial shrub that is represented in such high densities at late Woodland II occupations, is present but in low densities at the river bar sites, but at the later, more substantial sites, bramble density becomes quite high suggesting that the Late Woodland II pattern of bramble use had emerged. The Princess Point period was both a period of agricultural development and a time when the anthropogenic environment so valued by later agricultural peoples was emerging.

6 Lower Yangtze Valley, China, and the Problem of Rice Domestication

The environmental circumstances of plant domestication are crucial to understanding this evolutionary process. Domestication selects for traits that increase the fitness of certain organisms such as rice (*Oryza sativa*) in a human-mediated environmental context. Understanding rice domestication is a challenge because we need to understand the circumstances in which wild rice developed a connection with people. Rice can be harvested in the wild, but its seed production is relatively low compared to modern domesticated rice, and combined with asynchronous ripening, rice would not have been a significant resource until these traits changed (for a comprehensive discussion, see Crawford 2011b). Modern domesticated rice may hybridize among different varieties and also hybridizes with its wild ancestor, and this creates a weed that is not particularly desirable. Isolating new phenotypes in human created habitats would help maintain the new phenotypes and potentially accelerate their evolution. The earliest paddy fields date to between 7000 and 4000 BP (Zheng et al. 2009) and are associated with communities that were built on or very close to wetlands, so only limited isolation of the crop was achieved by this time. Given the circumstances, deterministic explanations relying on single causes such as population growth or climate change forcing people to domesticate organisms (lower-ranked resources according to the diet breadth model) because of resource imbalances have their difficulties because they tend to rely on correlations and the correlations are imprecise (e.g. Maher et al. 2011). Niche construction theory is opening other avenues of inquiry because it incorporates human-environment interaction and acknowledges an active human role in the environment. Niche construction theory can contribute to understanding how domestication takes place (Smith 2012). Human enhancement of certain taxa in these contexts would elevate their rank in an optimization model (Smith 2012). Smith incorporates climate change, resource catchment, traditional ecological knowledge, and the observation that domestication generally takes place in resource-rich areas such as river floodplain corridors and lake and marsh/estuary margins. The lower Yangzi Valley is just such a location.

The lower reaches of the Yangzi River lie within a few metres of sea level, and sites dating from about 8000 years ago have all been impacted by either flooding or sea level changes (e.g. Jiang et al. 2004; Shu et al. 2010; Zong et al. 2007) (Fig. 4). From oldest to youngest, the Kuahuqiao, Hemudu, Liangzhu, Guangfulin, and Maqiao cultures all have sites that are waterlogged or have components that are waterlogged. As a result, the most diverse plant remains assemblages in China are from these cultures (e.g. Jiang et al. 2004; Fuller et al. 2011; Pan 2017). Niche construction likely played a significant role in the early development of agriculture in the region (Pan 2017; Pan et al. 2017). Kuahuqiao and Xiasun are two Kuahuqiao culture sites (8000–7000 BP) situated on the perimeter of a wetland between two hilly ridges in the Yangzi delta. The location provided access to aquatic plant resources, a variety of habitats for animal resources that included migratory waterfowl and wading birds all of which are evidenced among the archaeological remains. The area is so rich given, for example, that in the spring and fall some estimates place over a million birds feeding in the Yangzi delta during their migration (Pan 2017). Aquatic resources are diverse in the region, so, unsurprisingly, several aquatic plants such as rice, foxnut (*Euryale ferox*), and water caltrop (*Trapa natans*) became economically important here. Furthermore, about three dozen plant families are represented among the remains from all period, and all plant parts are

Fig. 4 The Yuyao River near the Hemudu Site has a rich aquatic environment and floodplain near sea level

represented, including tubers and stems (Pan 2017; Fuller et al. 2011; Jiang 2013; Jiang et al. 2004; Zhejiang Provincial Museum 1978; Pan et al. 2017). Other plants commonly evidenced in these cultures include arboreal plants such as hog plum, plum, peach, apricot, and acorn. Acorn abundance is exceptional. Specially designed pits were constructed as early as 7500–7000 BP to store these nuts. A half-dozen pits at Kuahuqiao contained large numbers of acorns, while more than a dozen pits each filled with a roughly estimated 20,000 acorns have been discovered at the Tianluoshan site. Kuahuqiao evidences a diverse resource base from aquatic habitats, edge communities along wetland borders, and upland ecotones (Pan et al. 2017; Pan 2017).

Aquatic and terrestrial flora and fauna provisioned Kuahuqiao and Xiasun for about 1000 years, so Pan (2017) poses the question: how was the productivity of these resources maintained when wetland ecological succession would have led to aquatic biomass accumulation and ultimately the reduction of productive capacity of the ecosystem? Sustainable harvesting and hunting methods appear to have been essential for the maintenance of both Kuahuqiao culture villages (Pan et al. 2017). Abundant charcoal fragments in pollen cores are evidence for regular burning of the marshes around the site, and charcoal density is ten times higher during the occupation than prior to it (Innes et al. 2009; Shu et al. 2010; Zong et al. 2007). The charcoal fragments have not been identified; however, their source was likely from both the marshes and uplands. Oaks tend to be fire tolerant, so oak savannas develop when anthropogenic fires are set and where oaks are an important component of the vegetation. Peach, apricot, and plum are also fire tolerant. Many of these resources, then, were likely abundant, and their productivity maintained because of anthropogenic activities (Pan et al. 2017). Peach cultivation and domestication has its beginnings at Kuahuqiao too (Zheng et al. 2014). Water caltrop and foxnut were likely harvested by boat as they are today although wading to harvest them may also have been practiced. Both methods would cause some disturbance and introduce nutrients, thus increasing production somewhat. This harvesting method permitted continued dispersal of seed and maintenance of these plant populations (Pan 2017). Overharvesting would likely reduce the size of seeds and fruits, and, so far, this is not evidenced (Pan et al. 2017). Ultimately, some of these resources (e.g. pig, rice, peach) responded by developing phenotypes that benefited both people and the organisms themselves. At Kuahuqiao, terrestrial resources were more commonly exploited in the middle and later periods suggesting that the aquatic habitats were deteriorating, probably due to salinification associated with the sea level rise that forced abandonment of this lowland. On the whole, the major influence on local vegetation appears to have been anthropogenic rather than climate.

We knew little about what preceded the Kuahuqiao and subsequent cultures that were already cultivating rice to varying degrees until the discovery of the Shangshan culture about 10 years ago. Shangshan culture sites are situated in interior river basins at elevations ranging from about 40 to 100 m above sea level (Fig. 5). Shangshan, the type site for the culture, occupies a large portion of a terrace and has numerous pits and basins that may be houses (Jiang et al. 2016). In fact, all Shangshan culture sites are situated on terraces rather than on the floodplain, unlike the lowland sites such as Kuahuqiao and Tianluoshan. Two sites, Huxi and Qiaotou, have roughly 2-m-deep ditches associated with them. The reason for the ditches is not clear although ditches are common during the Neolithic of North and South China. They probably serve several purposes such as bringing water close to the community, establishing community boundaries, and refusing disposal. Phytoliths, seeds, and rice spikelet bases collected from the Huxi site ditch provide some insight into the ditch ecology through its lifespan (Zheng et al. 2016). The rice at Huxi is an early domesticated type and appears to have been growing close to, or in the ditch. As the ditch is filled with sediment, organic debris and human refuse also accumulated. Fewer rice glume phytoliths relative to rice leaf phytoliths were deposited than in the deeper deposits. Rice grains and rice spikelet bases have been recovered from the ditch sediments too. *Miscanthus* and *Phragmites*, common weeds in and near rice fields, are also represented in the phytoliths. *Phragmites* phytoliths are recovered in higher density in the later stages of the ditch when it was shallower. These ditches may play a role in bringing rice into direct contact with settlements or may have been purposefully constructed to do so along with its other purposes. The research also points to the usefulness of several lines of evidence, in this case phytoliths combined with larger plant remains such as rice spikelets. In an unrelated study in the Yiluo River valley, grass phytoliths were statistically assessed, and contextualized with reference to charred plant remains from the same sites, to deter-

Fig. 5 View from the Shangshan culture, Hehuashan site terrace overlooking the ancient floodplain of the Qujiang River. The site is situated in an upland, intermountain river basin

mine the extent to which wet versus dry systems existed (Weisskopf 2016). Likely, the rice was not grown in extensively irrigated fields like it was to the south.

7 Modelling

Quantitative reconstruction of vegetation may still be accomplished best by palynological research (Gaillard et al. 2008) but normally involves several lines of evidence. Reconstruction need not be limited to woodlands or woodland clearance but can also be applied to intensity and sustainability of agriculture, for example. A few examples of modelling techniques include agent-based and mechanistic crop growth models, the Landscape Reconstruction Algorithm (LRA), and POLLSCAPE (Baum et al. 2016; Gaillard et al. 2008; Mehl and Hjelle 2015). Modelling may also include experimental studies such as one that examined weed ecology and how it varies in different fertility and disturbance regimes (Bogaard et al. 2016). Among other problems being examined are whether field systems were permanent or shifting, whether burning was necessary to maintain fields, and the extent to which climate change and anthropogenic impacts trigger long-term vegetation changes, the role of irrigation, and the intensity and sustainability of agriculture (Saqalli et al. 2014; Pędziszewska and Latałowa 2015; Baum et al. 2016). Another approach proposes casting a wider net to build models using, for example, charred plant remains, climate and population movement data, and social constructs to model movement of agriculture to the Tibetan Plateau (d'Alpoim Guedes 2016). Modelling is the main approach of HBE, particularly the circumstances behind resource choices. A novel assessment of how to test risk (chance of loss) models using plant and animal remains explores diversification and intensification and how to measure them. Marston (2011) examines ratios of taxa, diversity indices, and weed patterns to assess diversification, while markers of irrigation and grazing versus foddering can help the role of intensification. Understanding risk is also crucial to resilience theory. GIS is also being employed but places less emphasis on plant remains and more emphasis on landscape "measurement" to detect spatial patterning in order to predict where, for example, maize may have been grown when agricultural was first developing in Mexico (Hanselka and King 2017). Another study involved experimental gardening in collaboration with the Hopi and emphasizes that both the environmental and cultural context are crucial (Sundjordet 2017). Ecological models, whether they be based on niche construction, optimal foraging, or a synthesis of the two, require considering a broad range of factors.

8 Summary

Archaeological plant remains including macro-remains, phytoliths, and pollen and non-pollen palynomorphs (NPP) are offering substantial insights into human-environment relationships. Palynology is still providing the predominant database for palaeoenvironmental reconstruction, while other archaeological plant remains tend to focus on identifying habitats that were being exploited. Much of the latest palaeoethnobotanical research that is the focus of this chapter is data-driven, empirical research with no explicit theoretical perspective. Popular topics include discerning the type of agriculture in a region, the impact of agriculture on landscapes, and the extent of clearing around archaeological sites. Agricultural origins are also an important focus. Much of the latest data on agricultural origins are being recovered in East Asia where basic research on the topic was lacking until about 15–20 years ago. Research is moving away from descriptive results and deterministic explanations to more nuanced understandings of human-environment interactions. Productive lines of inquiry are being pursued by situating palaeoethnobotany in the broader discourse of human ecology and ethnobiology. This means explicitly engaging with culture as well as the environment. Ethnographic research addressing archaeological issues related to human-plant interaction is providing important insight, particularly regarding modelling and identifying the unanticipated. Foci trending in theoretical discussions are human behavioural ecology (HBE) that emphasizes optimal foraging or diet breadth, historical ecology, resilience, anthropogenesis, and niche construction. Niche construction is broadening the discussion of anthropogenesis and the diet breadth model to a more nuanced conceptualization of human-environment interaction that includes considering intentional ecological engineering such as landscape management.

References

Anderson, E. (1971). *Plants, man and life*. Los Angeles: University of California Press.

Antolín, F., & Jacomet, S. (2014). Wild fruit use among early farmers in the Neolithic (5400–2300 cal bc) in the north-east of the Iberian Peninsula: An intensive practice? *Vegetation History and Archaeobotany, 24*(1), 19–33.

Balée, W. (2006). The research program of historical ecology. *Annual Review of Anthropology, 35*(1), 75–98.

Barth, F. (1956). Ecologic relationships of ethnic groups in Swat, North Pakistan. *American Anthropologist, 58*(6), 1079–1089.

Baum, T., Nendel, C., Jacomet, S., Colobran, M., & Ebersbach, R. (2016). "Slash and burn" or "weed and manure"? A modelling approach to explore hypotheses of late Neolithic crop cultivation in pre-alpine wetland sites. *Vegetation History and Archaeobotany, 25*(6), 611–627.

Bogaard, A., Hodgson, J., Nitsch, E., Jones, G., Styring, A., Diffey, C., et al. (2016). Combining functional weed ecology and crop stable isotope ratios to identify cultivation intensity: A comparison of cereal production regimes in Haute Provence, France and Asturias, Spain. *Vegetation History and Archaeobotany, 25*, 57–73.

Butzer, K. W. (1975). The ecological approach to archaeology: Are we really trying? *American Antiquity, 40*(1), 106–111.

Butzer, K. W. (1982). *Archaeology as human ecology: Method and theory for a contextual approach*. Cambridge/New York: Cambridge University Press.

Crawford, G. W. (1983). *Paleoethnobotany of the Kameda Peninsula Jomon*, *Anthropological papers no 73*. Ann Arbor: Museum of Anthropology, University of Michigan.

Crawford, G. W. (1987). Plant seeds excavated from the K135 site. In S.-s. K. Iinkai (Ed.), *K135 Iseki (the K135 site)* (pp. 565–581). Sapporo-shi Kyoiku Iinkai: Sapporo. (in Japanese).

Crawford, G. W. (1997). Anthropogenesis in prehistoric northeastern Japan. In K. Gremillion (Ed.), *People, plants, and landscapes: Studies in paleoethnobotany* (pp. 86–103). Tuscaloosa: University of Alabama Press.

Crawford, G. W. (1999). Northeastern palaeoethnobotany: How are we doing? In J. Hart (Ed.), *Northeast palaeoethnobotany* (pp. 225–234). Albany: New York State Museum.

Crawford, G. W. (2008). The Jomon in early agriculture discourse: Issues arising from Matsui, Kanehara, and Pearson. *World Archaeology, 40*(4), 445–465.

Crawford, G. W. (2011a). Advances in understanding early agriculture in Japan. *Current Anthropology, 53*(S4), S331–S345.

Crawford, G. W. (2011b). Early rice exploitation in the lower Yangzi valley: What are we missing? *The Holocene, 22*(6), 613–621.

Crawford, G. W. (2014). Food production and niche construction in pre-contact Southern Ontario. *Midcontinental Journal of Archaeology, Occasional Papers, 1*, 135–160.

Crawford, G. W., & Smith, D. G. (2003). Paleoethnobotany in the northeast. In P. E. Minnis (Ed.), *People and plants in ancient eastern North America* (pp. 172–257). Washington, DC: Smithsonian Books.

Crawford, G. W., & Takamiya, H. (1990). The origins and implications of late prehistoric plant husbandry in northern Japan. *Antiquity, 64*(245), 889–911.

Crawford, G. W., Smith, D. G., Desloges, J. R., & Davis, A. M. (1998). Floodplains and agricultural origins: A case study in south-central Ontario, Canada. *Journal of Field Archaeology, 25*(2), 123–137.

Crawford, G. W., Saunders, D., & Smith, D. G. (2006). Pre-contact maize from Ontario, Canada: Context, chronology, variation, and plant association. In J. Staller, R. Tykot, & B. Benz (Eds.), *Histories of maize: Multidisciplinary approaches to the prehistory, linguistics, biogeography, domestication, and evolution of maize* (pp. 549–559). Amsterdam: Elsevier.

d'Alpoim Guedes, J. (2016). Model building, model testing, and the spread of agriculture to the Tibetan Plateau. *Archaeological Research in Asia, 5*, 16–23.

D'Andrea, A. C. (1995). Archaeobotanical evidence for Zoku-Jomon subsistence at the Mochiyazawa site, Hokkaido, Japan. *Journal of Archaeological Science, 22*, 583–595.

D'Andrea, A. C., & Haile, M. (2002). Traditional emmer processing in highland Ethiopia. *Journal of Ethnobiology, 22*(2), 179–217.

Denevan, W. M. (1992). The pristine myth: The landscape of the Americas in 1492. *Annals of the Association of American Geographers, 82*(3), 369–385.

Dimbleby, G. W. (1978). *Plants and archaeology*. Atlantic Highlands: Humanities Press.

Dotte-Sarout, E. (2016). Evidence of forest management and arboriculture from wood charcoal data: An anthracological case study from two New Caledonia Kanak pre-colonial sites. *Vegetation History and Archaeobotany, 26*(2), 195–211.

Ford, R. I. (1978). Ethnobotany: Historical diversity and synthesis. In R. I. Ford (Ed.), *The nature and status of ethnobotany*, *Anthropological papers no. 67* (pp. 33–50). Ann Arbor: Museum of Anthropology, University of Michigan.

Ford, R. I. (1979). Paleoethnobotany in American archaeology. In M. Schiffer (Ed.), *Method and theory in American archaeology* (Vol. 2, pp. 285–336). New York: Academic Press.

Fuller, D. Q., Qin, L., Zhao, Z., Zheng, Y., Hosoya, L.-A., Chen, X., et al. (2011). Archaeobotanical analysis at Tian Luo Shan: Evidence for wild-food gathering, rice cultivation and the process of the evolution of morphologically domesticated rice. In School of Archaeology and Museology, Peking University and Zhejiang Provincial Institute of Archaeology (Ed.), *Studies of ecoremains from Tianluoshan site* (pp. 47–96). Beijing: Wenwu Press. (in Chinese).

Gaillard, M.-J., Sugita, S., Bunting, M. J., Middleton, R., Broström, A., Caseldine, C., et al. (2008). The use of modelling and simulation approach in reconstructing past landscapes from fossil pollen data: A review and results from the POLLANDCAL network. *Vegetation History and Archaeobotany, 17*(5), 419–443.

Gillreath-Brown, A., & Bocinsky, R. K. (2017). A dialogue between empirical and model-based agricultural studies in archaeology. *Journal of Ethnobiology, 37*(2), 167–171.

Gremillion, K. J. (2014). Human behavioral ecology and paleoethnobotany. In J. M. Marston (Ed.), *Method and theory in paleoethnobotany* (pp. 339–354). Boulder: University Press of Colorado.

Gunderson, L. H. (2000). Ecological resilience—In theory and application. *Annual Review of Ecology and Systematics, 31*, 425–439.

Habu, J. (2015). Mechanisms of long-term culture change and human impacts on the environment: A perspective from historical ecology, with special reference to the early and middle Jomon periods of prehistoric Japan. *The Quaternary Research, 54*(5), 299–310.

Hammett, J. (1992). The shapes of adaptation: Historical ecology of anthropogenic landscapes in the Southeastern United States. *Landscape Ecology, 7*(2), 121–135.

Hammett, J. (1997). Interregional patterns of land use and plant management in native North America. In K. J. Gremillion (Ed.), *People, plants, and landscapes: Studies in paleoethnobotany* (pp. 195–216). Tuscaloosa: University of Alabama Press.

Hanselka, J. K., & King, B. (2017). Modeling agricultural potential near the Ocampo Caves, Tamaulipas: Integrating archaeological and geospatial applications. *Journal of Ethnobiology, 37*(2), 260–281.

Hart, J., Asch, D. L., Scarry, C. M., & Crawford, G. W. (2002). The age of the common bean (*Phaseolus vulgaris* L.) in the northern Eastern Woodlands of North America. *Antiquity, 76*(292), 377–385.

Hastorf, C. (1999). Recent research and innovations in paleoethnobotany. *Journal of Archaeological Research, 7*(1), 55–103.

Heisey, R. M. (1997). Allelopathy and the secret life of *Ailanthus altissima*. *Arnoldia, 57*(3), 28–36.

Hodder, I., & Hutson, S. (2003). *Reading the past current approaches to interpretation in archaeology* (3rd ed.p. xviii., 293 p.). Cambridge, UK/New York: Cambridge University Press.

Imamura, K. (1996). *Prehistoric Japan: New perspectives on insular East Asia*. Honolulu: University of Hawaii Press.

Innes, J., Zong, Y., Chen, Z., Chen, C., Wang, Z., & Wang, H. (2009). Environmental history, palaeoecology and human activity at the early Neolithic forager/cultivator site at Kuahuqiao, Hangzhou, eastern China. *Quaternary Science Reviews, 28*(23–24), 2277–2294.

Jacobsen, T., & Adams, R. M. (1958). Salt and silt in ancient Mesopotamian agriculture. *Science, 128*(3334), 1251–1258.

Jiang, L. (2013). The Kuahuqiao site and culture. In A. P. Underhill (Ed.), *A companion to Chinese archaeology* (Vol. 24, pp. 537–554). Chichester/West Sussex: Wiley.

Jiang, L., Zheng, Y. F., Fang, X. M., et al. (2004). *Kuahuqiao*. Beijing: Cultural Relics Publishing House. (in Chinese).

Jiang, L., Sun, H., XIe, L., Wang, J., Wang, C., Xu, Y., et al. (2016). *Pujiang Shangshan*. Beijing: Cultural Relics Press. (in Chinese).

Johnston, R. B. (Ed.). (1984). *The McIntyre site: Archaeology, subsistence and environment, (National Museum of Man Mercury Series): Archaeological Survey of Canada Paper No. 26*. Ottawa: National Museums of Canada.

Kobayashi, T., Kaner, S., & Nakamura, O. (2004). *Jomon reflections: Forager life and culture in the prehistoric Japanese archipelago*. Oxford: Oxbow.

Lee, G.-A., & Crawford, G. W. (2011). Archaeological soybean (*Glycine max*) in East Asia: Does size matter? *PLoS One, 6*(11), e26720.

Letcher, S. G., Lasky, J. R., Chazdon, R. L., Natalia, N., Joseph Wright, S., Meave, J. A., Pérez-García, E. A., Muñoz, R., Romero-Pérez, E., Andrade, A., Andrade, J. L., Balvanera, P., Becknell, J. M., Bentos, T. V., Bhaskar, R., Bongers, F., Boukili, V., Brancalion, P. H. S., César, R. G., Clark, D. A., Clark, D. B., Craven, D., DeFrancesco, A., Dupuy, J. M., Finegan, B., González-Jiménez, E., Hall, J. S., Harms, K. E., Hernández-Stefanoni, J. L., Hietz, P., Kennard, D., Killeen, T. J., Laurance, S. G., Lebrija-Trejos, E. E., Lohbeck, M., Martínez-Ramos, M., Massoca, P. E. S., Mesquita, R. C. G., Mora, F., Muscarella, R., Paz, H., Pineda-García, F., Powers, J. S., Quesada-Monge, R., Rodrigues, R. R., Sandor, M. E., Sanaphre-Villanueva, L., Schüller, E., Swenson, N. G., Tauro, A., Uriarte, M., van Breugel, M., Vargas-Ramírez, O., Viani, R. A. G., Wendt, A. L., Bruce Williamson, G., & Zhou, S. (2015). Environmental gradients and the evolution of successional habitat specialization: a test case with 14 Neotropical forest sites. Journal of Ecology, 103(5), 1276–1290

Liu, D. L., & Lovett, J. V. (1993). Biologically active secondary metabolites of barley I. *Journal of Chemical Ecology, 19*(10), 2217–2230.

Lopes, P., & Begossi, A. (2009). *Current trends in human ecology*. Cambridge Scholars Pub: Newcastle upon Tyne.

López-Sáez, J. A., Glais, A., Robles-López, S., Alba-Sánchez, F., Pérez-Díaz, S., Abel-Schaad, D., et al. (2016). Unraveling the naturalness of sweet chestnut forests (*Castanea sativa* Mill.) in central Spain. *Vegetation History and Archaeobotany, 26*(2), 167–182.

Madella, M., Lancelotti, C., & Savard, M. (2014). *Ancient plants and people: Contemporary trends in archaeobotany*. Tucson: University of Arizona Press.

Maher, L. A., Banning, E. B., & Chazan, M. (2011). Oasis or mirage? Assessing the role of abrupt climate change in the prehistory of the southern Levant. *Cambridge Archaeological Journal, 21*(01), 1–30.

Marston, J. M. (2011). Archaeological markers of agricultural risk management. *Journal of Anthropological Archaeology, 30*(2), 190–205.

Marston, J. M., d'Alpoim Guedes, J. & Warinner, C. (2014). *Method and theory in paleoethnobotany*. Boulder: University Press of Colorado.

McCay, B. J. (2008). An intellectual history of ecological anthropology. In B. B. Walters, B. J. Mccay, P. West, & S. Lees (Eds.), *Against the grain: The Vayda tradition in human ecology and ecological anthropology* (pp. 11–26). Lanham: Altamira Press.

Mehl, I. K., & Hjelle, K. L. (2015). From deciduous forest to open landscape: Application of new approaches to help understand cultural landscape development in western Norway. *Vegetation History and Archaeobotany, 25*(2), 153–176.

Messner, T. C., & Stinchcomb, G. E. (2014). Peopling the environment: Interdisciplinary inquiries into socioecological systems incorporating palaeoclimatology and geoarchaeology. In J. M. Marston (Ed.), *Method and theory in paleoethnobotany* (pp. 257–274). Boulder: University Press of Colorado.

Miller, N. (2014). Vegetation proxy data and climate reconstruction. In M. Madella, C. Lancelotti, & M. Savard (Eds.), *Ancient plants and people: Contemporary trends in archaeobotany* (pp. 120–134). Tucson: University of Arizona Press.

Minnis, P. (1978). Paleoethnobotanical indicators of prehistoric environmental disturbance: A case study. In R. I. Ford (Ed.), *The nature and status of ethnobotany*, *Anthropological papers, 67* (pp. 347–366). Ann Arbor: Museum of Anthropology, University of Michigan.

Monckton, S. G. (1992). *Huron paleoethnobotany*, *Ontario archaeological reports 1*. Toronto: Ontario Heritage Foundation.

Nagaoka, L., & Wolverton, S. (2016). Archaeology as ethnobiology. *Journal of Ethnobiology, 36*(3), 473–475.

Noshiro, S., & Sasaki, Y. (2014). Pre-agricultural management of plant resources during the Jomon period in Japan—A sophisticated subsistence system on plant resources. *Journal of Archaeological Science, 42*, 93–106.

Oas, S. E., D'Andrea, A. C., & Watson, D. J. (2015). 10,000 year history of plant use at Bosumpra Cave, Ghana. *Vegetation History and Archaeobotany, 24*(5), 635–653.

Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (2003). *Niche construction: The neglected process in evolution*, *Monographs in population biology* (Vol. 37). Princeton: Princeton University Press.

Odum, E. P. (1963). *Fundamentals of ecology* (2d ed.). Philadelphia: Saunders.

Odum, E. P. (1969). The strategy of ecosystem development. *Science, 164*(3877), 262–270.

Odum, E. P. (1975). *Ecology: The link between the natural and the social sciences*, *Modern biology series* (2d ed.). New York: Holt.

Odum, E. P. (1983). *Basic ecology*. Philadelphia: Saunders College Pub.

Ounjian, G. (1998). *Glen Meyer and Neutral palaeoethnobotany*. Ph.D. Dissertation, Department of Anthropology, University of Toronto.

Pan, Y. (2017). *A human ecological perspective on the origin of agriculture in the lower reaches of the Yangzi Valley*. Shanghai: Shanghai Lexicographical Publishing House. (in Chinese).

Pan, Y., Zheng, Y., & Chen, C. (2017). Human ecology of the early Neolithic Kuahuqiao culture in East Asia. In J. Habu (Ed.), *Encyclopedia of east and southeast Asian archaeology* (p. TBA). New York: Springer Science + Business Media.

Pędziszewska, A., & Latałowa, M. (2015). Stand-scale reconstruction of late Holocene forest succession on the Gdańsk Upland (N. Poland) based on integrated palynological and macrofossil data from paired sites. *Vegetation History and Archaeobotany, 25*(3), 239–254.

Ramsay, J., & Holum, K. (2015). An archaeobotanical analysis of the Islamic period occupation at Caesarea Maritima, Israel. *Vegetation History and Archaeobotany, 24*(6), 655–671.

Rappaport, R. A. (1971). The flow of energy in an agricultural society. *Scientific American, 225*(3), 116–132.

Redman, C. L. (1999). *Human impact on ancient environments*. Tucson: University of Arizona Press.

Redman, C. L. (2005). Resilience theory in archaeology. *American Anthropologist, 107*(1), 70–77.

Redman, C. L., & Kinzing, A. P. (2003). Resilience of past landscapes: Resilience theory, society, and the longue durée. *Conservation Ecology, 7*(1), 14.

Reice, S. R. (1994). Nonequilibrium determinants of biological community structure. *American Scientist, 82*(5), 424–435.

Renfrew, J. M. (1973). *Palaeoethnobotany: The prehistoric food plants of the Near East and Europe*. New York: Columbia University Press.

Riehl, S. (2014). Significance of prehistoric weed floras for the reconstruction of relations between environment and crop husbandry practices in the Near East. In M. Madella, C. Lancelotti,

& M. Savard (Eds.), *Ancient plants and people : Contemporary trends in archaeobotany* (pp. 135–152). Tucson: University of Arizona Press.

Rindos, D. (1984). *The origins of agriculture: An evolutionary perspective*. San Diego: Academic Press.

Saqalli, M., Salavert, A., Bréhard, S., Bendrey, R., Vigne, J.-D., & Tresset, A. (2014). Revisiting and modelling the woodland farming system of the early Neolithic Linear Pottery Culture (LBK), 5600–4900 b.c. *Vegetation History and Archaeobotany, 23*(S1), 37–50.

Sasaki, Y., & Noshiro, S. (2004). Utilization of forest resources in the Late Jomon Period deduced from wooden remains for water usage at the Shimo-yakebe site, Tokyo, Japan. *Japanese Journal of Historical Botany, 12*(1), 37–46. (in Japanese).

Sato, Y., Yamanaka, S., & Takahashi, M. (2003). Evidence for Jomon plant cultivation based on DNA analysis of chestnut remains. In J. Habu, J. M. Saveille, S. Koyama, & H. Hongo (Eds.), *Hunter-gatherers of the North Pacific Rim*, *Senri ethnological studies 63* (pp. 187–197). Osaka: National Museum of Ethnology.

Saunders, D. (2002). *Princess point palaeoethnobotany*. Ph.D., University of Toronto, Toronto.

Sayre, M. P., & Bruno, M. C. (2017). *Social perspectives on ancient lives from paleoethnobotanical data*. Gewerbestrasse: Springer International Publishing.

Shu, J., Wang, W., Jiang, L., & Takahara, H. (2010). Early Neolithic vegetation history, fire regime and human activity at Kuahuqiao, Lower Yangtze River, East China: New and improved insight. *Quaternary International, 227*(1), 10–21.

Smith, B. D. (2012). A cultural niche construction theory of initial domestication. *Biological Theory, Online, 6*, 260–271.

Smith, B. D. (2014). Documenting human niche construction in the archaeological record. In J. M. Marston (Ed.), *Method and theory in paleoethnobotany* (pp. 355–370). Boulder: University Press of Colorado.

Smith, D. G., & Crawford, G. W. (1997). Recent developments in the archaeology of the princess point complex in Southern Ontario. *Canadian Journal of Archaeology, 21*, 9–32.

Sundjordet, S. (2017). Let them plant their own: Implications of interactive crop-loss processes during drought in Hopi maize fields. *Journal of Ethnobiology, 37*(2), 241–259.

Takase, K. (2014). Use of resources and land in the Epi-Jomon culture: Perspectives based on the comparative study with adjacent cultures. *National Institute of History and Folklore, 185*, 15–62. (in Japanese).

VanDerwarker, A. M., Bardolph, D. N., Hoppa, K. M., Thakar, H. B., Martin, L. S., Jaqua, A. L., et al. (2015). New world paleoethnobotany in the new millennium (2000–2013). *Journal of Archaeological Research, 24*(2), 125–177.

Vayda, A. P. (1969). An ecological approach in cultural anthropology. *Bucknell Review, 17*(1), 112–119.

Vayda, A. P., & Mccay, B. J. (1975). New directions in ecology and ecological anthropology. *Annual Review of Anthropology, 4*, 293–306.

Walker, I. J., Desloges, J. R., Crawford, G. W., & Smith, D. G. (1997). Floodplain formation processes and archaeological implications, Lower Grand River, Southern Ontario. *Geoarchaeology, 12*(8), 865–887.

Weisskopf, A. (2016). A wet and dry story: Distinguishing rice and millet arable systems using phytoliths. *Vegetation History and Archaeobotany, 26*(1), 99–109.

Willey, G. R., & Sabloff, J. A. (1993). *A history of American archaeology* (3rd ed.). New York: W.H. Freeman.

Winterhalder, B., & Smith, E. A. (2000). Analyzing adaptive strategies: Human behavioral ecology at twenty-five. *Evolutionary Anthropology, 9*(2), 51–72.

Wright, P. J. (2010). Methodological issues in paleoethnobotany: A consideration of issues, methods, and cases. In A. M. VanDerwarker & T. M. Peres (Eds.), *Integrating zooarchaeology and paleoethnobotany: A consideration of issues, methods, and cases* (pp. 37–64). New York: Springer New York.

Yarnell, R. A. (1963). Reciprocity in cultural ecology. *Economic Botany, 17*(4), 333–336.

Yarnell, R. A. (1964). *Aboriginal relationships between culture and plant life in the Upper Great Lakes Region*, *Anthropological papers no. 23*. Ann Arbor: Museum of Anthropology, University of Michigan.

Yarnell, R. A. (1965). Implications of distinctive flora on pueblo ruins. *American Anthropologist, 67*, 662–674.

Yarnell, R. A. (1982). Problems of interpretation of archaeological plant remains of the eastern woodlands. *Southeastern Archaeology, 1*(1), 1–7.

Yarnell, R. A. (1984). The McIntyre site: Late archaic plant remains from Southern Ontario. In R. B. Johnston (Ed.), *The McIntyre site: Archaeology, subsistence and environment*, *National Museum of man mercury series, paper no. 126* (pp. 87–111). Ottawa: National Museums of Canada.

Zeder, M. A. (2016). Domestication as a model system for niche construction theory. *Evolutionary Ecology, 30*(2), 325–348.

Zhejiang Provincial Museum, N. H. S. (1978). A study of animal and plant remains unearthed at Hemudu. *Kaogu, 1*, 95–111. (in Chinese).

Zheng, Y., Sun, G., Qin, L., Li, C., Wu, X., & Chen, X. (2009). Rice fields and modes of rice cultivation between 5000 and 2500 BC in east China. *Journal of Archaeological Science, 36*(12), 2609–2616.

Zheng, Y., Crawford, G. W., & Chen, X. (2014). Archaeological evidence for peach (*Prunus persica*) cultivation and domestication in China. *PLoS One, 9*(9), e106595.

Zheng, Y., Crawford, G. W., Jiang, L., & Chen, X. (2016). Rice domestication revealed by reduced shattering of archaeological rice from the Lower Yangtze valley. *Scientific Reports, 6*, 28136.

Zong, Y., Chen, Z., Innes, J. B., Chen, C., Wang, Z., & Wang, H. (2007). Fire and flood management of coastal swamp enabled first rice paddy cultivation in east China. *Nature, 449*(7161), 459–462.