Quaternary International 489 (2018) 101–120

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Subsistence mosaics, forager-farmer interactions, and the transition to food production in eastern Africa

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ARTICLE INFO

Article history:
Received 16 March 2016
Received in revised form
8 December 2016
Accepted 13 January 2017
Available online 1 March 2017

Keywords:
Bantu expansion
Iron age
Pastoralism
Agriculture
Archaeobotany
Zooarchaeology

ABSTRACT

The spread of agriculture across sub-Saharan Africa has long been attributed to the large-scale migration of Bantu-speaking groups out of their west Central African homeland from about 4000 years ago. These groups are seen as having expanded rapidly across the sub-continent, carrying an 'Iron Age' package of farming, metal-working, and pottery, and largely replacing pre-existing hunter-gatherers along the way. While elements of the 'traditional' Bantu model have been deconstructed in recent years, one of the main constraints on developing a more nuanced understanding of the local processes involved in the spread of farming has been the lack of detailed archaeobotanical and zooarchaeological sequences, particularly from key regions such as eastern Africa. Situated at a crossroads between continental Africa and the Indian Ocean, eastern Africa was not only a major corridor on one of the proposed Bantu routes to southern Africa, but also the recipient of several migrations of pastoral groups from the north. In addition, eastern Africa saw the introduction of a range of domesticates from India, Southeast Asia, and other areas of the Indian Ocean sphere through long-distance maritime connections. The possibility that some Asian crops, such as the vegecultural 'tropical trio' (banana, taro, and yam), arrived before the Bantu expansion has in particular raised many questions about the role of eastern Africa's non-agricultural communities in the adoption and subsequent diffusion of crops across the continent. Drawing on new botanical and faunal evidence from recent excavations at a range of hunter-gatherer and early farming sites on eastern Africa's coast and offshore islands, and with comparison to inland sites, this paper will examine the timing and tempo of the agricultural transition, the nature of forager-farmer-pastoralist interactions, and the varying roles that elements of the 'Bantu package', pastoralism, and non-African domesticates played in local economies. This paper highlights the complex pathways and transitions that unfolded, as well as how eastern Africa links into a broader global picture of heterogeneous, dynamic, and extended transformations from forager to farmer that challenge our fundamental understanding of pre-modern Holocene societies.

1. Introduction

Nearly one hundred years after V. Gordon Childe (1936) coined the term 'Neolithic Revolution' to refer to the shift to food production that occurred in various societies globally from the early Holocene, major debates continue to surround our understanding of this transition. In particular, the expansion of agriculture out of core centers of domestication, and the contrasting roles hypothesized for processes of migration, diffusion, replacement, and assimilation, remain key foci of study and discussion. At the heart of the debate concerning the mechanisms and agents involved in the prehistoric spread of agriculture are polarized models that specify primary roles for either migrating farmers or indigenous foragers. With their roots in contrasting hypotheses developed to explain the agricultural expansion across Europe from the Near East (e.g., Dennell, 1983; Ammerman and Cavalli-Sforza, 1984; Price and Gebauer, 1995; Cavalli-Sforza, 2002; Pinhasi and von Cramon-

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http://dx.doi.org/10.1016/j.quaint.2017.01.014

Taubadel, 2009; Morelli et al., 2010), these hypotheses have come to dominate views on the spread of agriculture in nearly every region of the world. Key to addressing the broad question posed by this special volume, 'Did foragers adopt farming', is the development of empirically-informed regional models for farming dispersals based on the systematic collection of well-dated archaeobotanical and zooarchaeological data. Indeed, where such datasets are accumulating worldwide, it is becoming increasingly clear that the spread of agriculture was a complex and multi-faceted process that, at different times and places, included historically-contingent factors of migration, diffusion, interaction and innovation (e.g., Fuller, 2006; Zeder, 2008; Barker, 2009; Baird et al., 2012; Denham, 2013; Spengler et al., 2014; among many others).

Although often marginalized or overlooked in the development of models for agricultural origins, Africa presents unique and theoretically informative case studies for global comparison. Eastern Africa is of particular interest for understanding farming expansions, not only because of its location encompassing the hypothesized migration routes of Bantu-speaking farmers and Cushitic- and Nilotic-speaking herders (Fig. 1), but also owing to its potentially early involvement in Indian Ocean trade, which brought novel domesticated plants and animals to its shores in prehistory. It has been suggested that eastern Africa's pre-agricultural communities had a role in dispersing vegetative crops such as banana (*Musa* spp.), taro (*Colocasia esculenta*), and Asian yam (*Dioscorea alata*) (all of which were first domesticated thousands of kilometers to the east in Sahul) across the tropical forests of Africa as early as the first millennium BCE (De Langhe, 2007; Blench, 2009).

A major hindrance to the development and refinement of models for the spread of agriculture in sub-Saharan Africa and the arrival of Indian Ocean crops has been the lack of large-scale, systematically collected, and directly AMS dated archaeobotanical and zooarchaeological data (see Boivin et al., 2013; Lane, 2015 for recent reviews). Until recently, few archaeological projects in Africa employed flotation and other methodologies explicitly aimed at recovering archaeobotanical materials—a situation particularly pronounced in regions outside the main centers of crop origins, where most systematic archaeobotanical efforts have been focused (see studies reviewed in Fuller and Hildebrand, 2013; Fuller et al., 2014). This lacuna has hindered not only agricultural origins research, but also our understanding of how agriculture spread relative to other food production systems such as pastoralism (as noted by Marshall, 1991; Marshall and Hildebrand, 2002), as well as what social conditions underpinned the transitions to food production (discussed by Lane, 2004). In the absence of empirical archaeobotanical and zooarchaeological evidence, most narratives relating to the origins and spread of farming across vast swathes of the sub-continent have been told by historical linguistics, and based on an assumed correlation between archaeological cultures and the spread of food producers (e.g., Ehret, 1974; Philippson and Bahuchet, 1994-95; Ehret, 2002; Phillipson, 2002, 2005). Inadequate datasets have hindered the emergence of more subtle narratives for eastern African prehistory that recognize local complexity, and the operation of diverse processes of replacement, admixture, interaction and resistance in encounters between expanding and existing populations, as well as less dualistic classifications of 'farmers' and 'foragers'. These considerations have been addressed by several researchers in discussions of late Holocene socioeconomic 'mosaics' in eastern Africa (see Section 2 below), but further exploration is impossible without new archaeological datasets.

In this paper, we draw on the results of a recent program of systematic archaeobotanical and zooarchaeological research to attempt a more nuanced discussion of the process by which agriculture spread to the eastern African coast and offshore islands (Fig. 2) over the past two millennia. We not only examine evidence for the roles of 'foragers', 'farmers', and 'herders' in the agricultural transition, but in light of growing evidence showing the fluid and dynamic nature of subsistence during the early farming period, we also discuss the ambiguity of applying these terms archaeologically in eastern Africa (see also Kusimba, 2003; Kusimba and Kusimba, 2005; Kusimba, 2005). We highlight the often poor archaeological visibility of early food production at sites from this region, and consider how this impacts our ability to develop empirically-informed models for the spread of farming. We conclude by discussing the implications of emerging evidence from eastern Africa for broader understandings of agricultural origins and spread, particularly in tropical contexts.

2. Models for early farming in eastern Africa

2.1. Background to African crop and livestock origins

Africa presents unique case studies for agricultural origins research. African pathways to food production were not only regionally diffuse and diverse, but also followed different trajectories to those of more familiar Near Eastern and East Asian narratives in which sedentary foragers become farmers around the turn of the Holocene. In Africa, in contrast, food production initially focused on mobile herding, with crop domestication developing several millennia later in a number of geographically separate centers in the southern Sahara, the Sahel, and Ethiopia (Fig. 1) (Marshall and Hildebrand, 2002; Fuller and Hildebrand, 2013; Lane, 2015). Mobile herding economies focused on cattle (*Bos taurus*), goat (*Capra hircus*), and sheep (*Ovis aries*). The latter two species were introduced to the continent from southwestern Asia by c. 6000 BCE, with proposed translocation routes including the Sinai, Mediterranean and Red Sea coasts, and the Horn. An earlier and contested independent domestication has been proposed for cattle c. 8000–6000 BCE from wild populations of *Bos primigenius africanus* in northeastern Africa (evidence reviewed by Gifford-Gonzalez, 2005; Marshall and Weissbrod, 2011; Stock and Gifford-Gonzalez, 2013); alternatively or additionally, cattle could have been introduced from southwestern Asia. Another African domesticate, often overlooked, is the donkey (*Equus asinus*), which appears on the basis of genetic and limited archaeological data to have been domesticated in two separate events, perhaps as early as the 5th millennium BCE, from populations of wild ass (*Equus africanus*) in northeastern Africa, and possibly also Arabia (Marshall and Weissbrod, 2011; Kimura et al., 2013).

Native African crops were domesticated in at least five different centers of origin (Fig. 1), from which they dispersed not only across the continent and to southern Africa by the late first millennium CE (Mitchell, 2002; Boivin et al., 2013), but also—and, remarkably, much earlier—as far as the Indian subcontinent by the start of the second millennium BCE (Fuller, 2003; Fuller and Boivin, 2009). The crops most relevant to our study are the three major African cereals, pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), and finger millet (*Eleusine coracana*), and the legume cowpea (*Vigna unguiculata*). Pearl millet derives from the West African Sahelian zone, with archaeobotanical evidence for its domestication dating from the second half of the third millennium BCE in northeast Mali (Kahlheber and Neumann, 2007; Manning et al., 2011). Sorghum appears to have been domesticated on the northeastern savannas of Sudan sometime before 2000 BCE (Stemler et al., 1975; Beldados and Costantini, 2011; Fuller, 2014). The third major indigenous African cereal, finger millet, was probably first brought into cultivation somewhere between the uplands of Ethiopia and the Great Lakes region

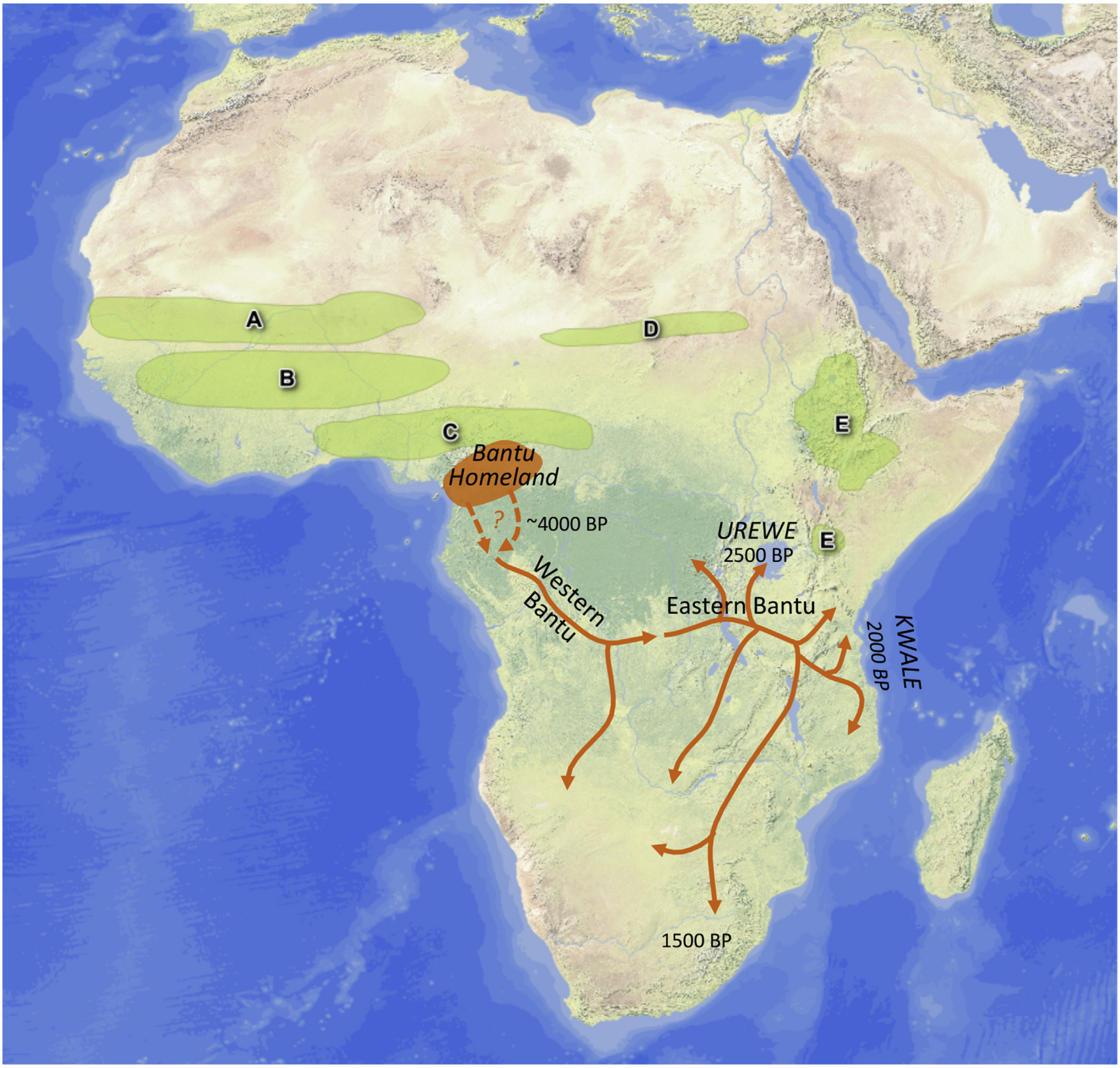

Fig. 1. Map of Africa showing the main centers of crop origins (A–E) (after Fuller and Hildebrand, 2013) and hypothesized routes of Bantu dispersal from Nigeria-Cameroon to eastern and southern Africa (orange arrows) (after Grollemund et al., 2015). A: West African Sahel (pearl millet); B: West African grassy woodlands (cowpea, baobab); C: Forest margins (yams, oil palm, *Canarium*); D: East Sudanic grasslands (sorghum); E: Ethiopian and eastern African uplands (finger millet). The Bantu dispersal to eastern Africa is associated archaeologically with Early Iron Age Urewe and Kwale pottery in the interior and coast region respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of eastern Africa, though the timing of this process is still unclear (Fuller, 2003; Fuller and Hildebrand, 2013). Cowpea, as well as the economically and culturally important baobab tree (*Adansonia digitata*), both originated in the West African savannas and have been documented in archaeobotanical assemblages of this region dating from around 2000–1500 BCE (D'Andrea et al., 2007; Kahlheber and Neumann, 2007). A wide range of other cereal, legume, fruit, arboricultural, and vegetative crops were also domesticated in Africa (see Fuller and Hildebrand, 2013), but as there is little evidence to connect their dispersal to eastern Africa at this stage, we do not discuss them in this paper.

2.2. Spread of farming to eastern Africa: the Bantu migration model

Since the 1960s, the dominant model for the spread of agriculture to eastern Africa has been founded on historical linguistic hypotheses and on ceramic '*fossiles directeurs*' rather than archaeobotanical and zooarchaeological data, and has linked this process to the large-scale movement of speakers of Bantu languages across sub-Saharan Africa in the mid-late Holocene. According to the classification of Greenberg (1963), Bantu belongs to one of the four major language families spoken by present-day peoples in Africa. Bantu languages are widely distributed throughout central, eastern,

Fig. 2. Map of eastern Africa showing sites mentioned in text.

and southern Africa today. Bantu-speaking populations are argued to have begun dispersing out of their linguistic and cultural homeland in West Africa, specifically in the Nigeria-Cameroon border area (Fig. 1), around 2000–1000 BCE, reaching southern Africa by 500 CE (e.g., de Filippo et al., 2012). This dispersal has now been traced genetically through both Y-chromosome and mitochondrial DNA (mtDNA) in modern African populations (Pereira et al., 2001; Salas and Richards, 2002; Richards et al., 2004; Pakendorf et al., 2011). It has also been linked archaeologically to the simultaneous spread of an 'Iron Age' cultural package that included agropastoralism, iron-working, and specific pottery types (e.g., Oliver, 1966; Huffman, 1970, 2006; Phillipson, 2005, 2007; see Mitchell, 2002; de Maret, 2013 for recent reviews). The Bantu expansion is thus widely seen as a powerful model linking archaeological, linguistic, and genetic evidence for sub-Saharan Africa, and has attracted global attention as an example of the Farming/Language Dispersal Hypothesis (e.g., Bellwood and Renfrew, 2002; Diamond and Bellwood, 2003; Bellwood, 2005; Robertshaw, 2013).

The Bantu migration is proposed to have followed two main routes (Fig. 1): a western stream that carried a mixed horticultural (yam-based)–arboricultural (*Canarium*/oil palm nut-based) complex south toward the Congo region, and a slightly later eastern stream that brought iron-working, cereal agriculture and domesticated livestock via the Great Lakes region (considered a secondary point of dispersal on this route) to the east coast and islands, and then to southern Africa (de Maret, 2013; Bostoen, 2014; Russell et al., 2014; Bostoen et al., 2015). Linguistic and genetic data suggest the Bantu migration to eastern Africa occurred between 3000 and 2000 years ago (Pereira et al., 2001; Salas and Richards, 2002; Wood et al., 2005; Tishkoff et al., 2009; Schienfeldt et al., 2010; Gomes et al., 2015; Grollemund et al., 2015). This broadly coincides with the period referred to as the Early Iron Age (EIA), when iron-working as well as two distinctive types of ceramics, considered diagnostic of this cultural phase, first appear in the archaeological record: Urewe in the Great Lakes region (c. 500 BCE–700 CE) (e.g., Leakey et al., 1948; Posnansky, 1961) and Kwale on the coast and in the coastal hinterland (c. 100–600 CE) (e.g., Soper, 1967; Chami, 1992; Helm, 2000). Ceramics with similar morphological and stylistic affinities, known as Matola ware, also trace the Iron Age dispersal to southern Africa, the result of a migration that occurred within a few centuries of Bantu arrival in eastern Africa (Sinclair et al., 1993).

Table 1
Summary of late Holocene archaeological traditions and associated subsistence strategies in eastern Africa.

Years CE/BP (approx.)	Archaeological periods (often overlapping)	Archaeological traditions and associated subsistence strategies[a], where known		
		Lake Victoria basin	Rift Valley and adjacent highlands	Coast and hinterland
c. 1000 CE	Later Iron Age (LIA), Pastoral Iron Age (PIA)	Cord/roulette ware	Sirikwa, Lanet, Kisima (HE)	Late Tana Tradition, Swahili ware, Plain ware (FI, AG, HE, HG)
c. 700 CE	Middle Iron Age (MIA), Pastoral Iron Age (PIA)	Urewe (HE, FI, AG, HG)	Lelesu (?), Savanna Pastoral Neolithic (Akira, Marangishu, Turkwel)[b] (HE, HG), Elmenteitan (HE)	Early Tana Tradition/Triangle Incised Ware (FI, AG, HE, HG)
c. 0 BCE/CE	Early Iron Age (EIA), Pastoral Neolithic (PN), Later Stone Age (LSA)	Urewe (HE, FI, AG, HG), Elmenteitan (HE, FI, HG)		Kwale/Early Iron Working (FI, HE, HG, AG)
c. 1000 BCE	Pastoral Neolithic (PN), Later Stone Age (LSA)	Elmenteitan (HE, FI, HG), Kansyore (FI, HG, HE)	Savanna Pastoral Neolithic (Narosura) (HE), Elmenteitan (HE)	aceramic LSA (HG)
c. 2000 BCE	Pastoral Neolithic (PN), Later Stone Age (LSA)	Kansyore (FI, HG, HE)	Nderit (HE, HG),Eburran 5 (HG)	aceramic LSA (HG)

[a] Main basis of economy, in order of importance as inferred from botanical and faunal remains where available: HG = hunting and gathering; FI = fishing; HE = cattle and/or caprine herding; AG = agriculture.
[b] Note that there is considerable debate as to the utility of ceramic 'types' within the Savanna Pastoral Neolithic (for a recent summary, see Ashley and Grillo, 2015).

2.3. *From migrations to mosaics*

Bantu-speaking agropastoral groups arriving in eastern Africa would have encountered an economically, socially, and linguistically complex landscape. Much of eastern Africa c. 1000 BCE was populated by foragers whose archaeological traces are attributed to the terminal Later Stone Age (LSA). Many scholars associate LSA foragers with click languages like those spoken by the Hadza or Sandawe today (e.g., Greenberg, 1963), and it has been suggested that the Bantu expansion resulted in the widespread displacement or assimilation of such populations (Phillipson, 1985; Diamond and Bellwood, 2003). Terminal LSA foragers were, however, far from homogenous, as shown by recent studies attesting to cultural and economic variation (Dale and Ashley, 2010; Prendergast, 2010), and would likely have reacted to the arrivals of food producers in diverse ways. Additionally, there were multiple migrations of livestock herders during the Pastoral Neolithic (PN) era (c. 3000 BCE–700 CE), prior to and during the Bantu expansion. Cattle and caprine herding, likely aided by donkeys, spread via Sudan and/or Ethiopia to northern Kenya as early as 3000–2500 BCE, and became widespread in Kenya and Tanzania after 1000 CE (Marshall et al., 2011; Gifford-Gonzalez, 2017). These early migrations of pastoralists—whose diverse archaeological vestiges have been grouped under the term Savanna Pastoral Neolithic (SPN)—have been linked by some scholars to the spread of Southern Cushitic languages (Ehret, 1998). The Bantu expansion is implicated in the disappearance of Cushitic languages from much of the region. A distinct PN archaeological tradition, the Elmenteitan, has been linked by some scholars to Southern Nilotic speakers (Ambrose, 1982), while traditions of the Pastoral Iron Age (PIA), in the late 1st/early 2nd millennium CE, are sometimes seen as emerging from the Elmenteitan (Ambrose et al., 1984; Lane, 2013). As this outline (summarized in Table 1) suggests, a dominant feature of life in first-millennium CE eastern Africa was diversity and probably degrees of fluidity between linguistic, social, and economic entities, whose 'boundaries' are often made overly firm by cultural-historical divisions such as LSA, PN, and EIA, all of which actually overlapped in space and time.

Growing recognition of such regional variability and cultural interaction as 'Iron Age' cultures spread has led to critiques of many aspects of the Bantu migration model (e.g., Vansina, 1995; Ehret, 2001; Lane, 2004; C. Kusimba and S. Kusimba, 2005; Wright, 2005; Lane, 2011, 2013; de Maret, 2013; Shipton et al., 2013). Data from both archaeology and linguistics show that the Bantu package itself was not as tightly packed as once thought, with traits such as iron-working and cereal agriculture only being acquired after these groups left their homeland, as part of a multi-phase process (Ehret, 1998; Casey, 2005; Neumann, 2005; Ricquier and Bostoen, 2011; de Maret, 2013). Linguistic data now suggest that Bantu-speaking agriculturalists obtained sorghum and pearl millet and possibly iron-working from Nilotic-speaking groups in the northern Great Lakes/southern Sudan region before dispersing southwards and eastwards towards the Indian Ocean coast (Schoenbrun, 1993; Philippson and Bahuchet, 1994-95; Ehret, 1998; Bostoen, 2006–07). Meanwhile, finger millet is suggested to have been spread southwards from the Ethiopian uplands by Cushitic rather than Bantu-speaking groups (Ehret, 1998, 2002), making it a relatively late addition to the so-called Bantu crop package that spread to southern Africa. There is very little archaeobotanical evidence to support these hypotheses (Fig. 3). Until now only three studies had ever reported direct evidence of crop remains from EIA sites in eastern Africa. Sorghum, pearl millet, and cowpea have been reported from contexts dating to around 400 cal CE in association with Urewe ceramics at Kabusanze in Rwanda (Giblin and Fuller, 2011; see also Van Grunderbeek and Roche, 2007, for pollen evidence, though this is considered non-diagnostic), finger millet from contexts dating to c. 800 CE at Deloraine Farm in western Kenya (Ambrose et al., 1984), and pearl millet and sorghum from undated EIA sites in the Mikindani region of southern Tanzania (Pawlowicz, 2011). In addition, there are two reports of sorghum and one probable pearl millet grain from c. 4th century CE contexts in Zambia, Zimbabwe, and northern South Africa (Fig. 3; Mitchell, 2002). This paucity of archaeobotanical evidence has continued to force archaeologists to privilege linguistics in developing more nuanced farming dispersal models for this region.

Recent commentaries have highlighted the importance of subsistence mosaics during the agricultural transition, broadly defined as landscapes of interaction between co-existing peoples with diverse (and often overlapping) ethnic, linguistic, political, economic and social backgrounds (Moore, 1985; Kusimba, 2003; Stahl, 2004; Kusimba and Kusimba, 2005; Kusimba et al., 2005; Shipton et al., 2013). Thus, rather than chronologically bounded cultural groups replacing one another in progression, as implicit in the traditional Bantu migration model, evidence suggests that there existed an ethnically and economically diverse frontier in which groups interacted at different spatial and temporal scales in relationships involving competition, conflict, exchange, symbiosis and/or assimilation. Certainly, eastern Africa's wide environmental

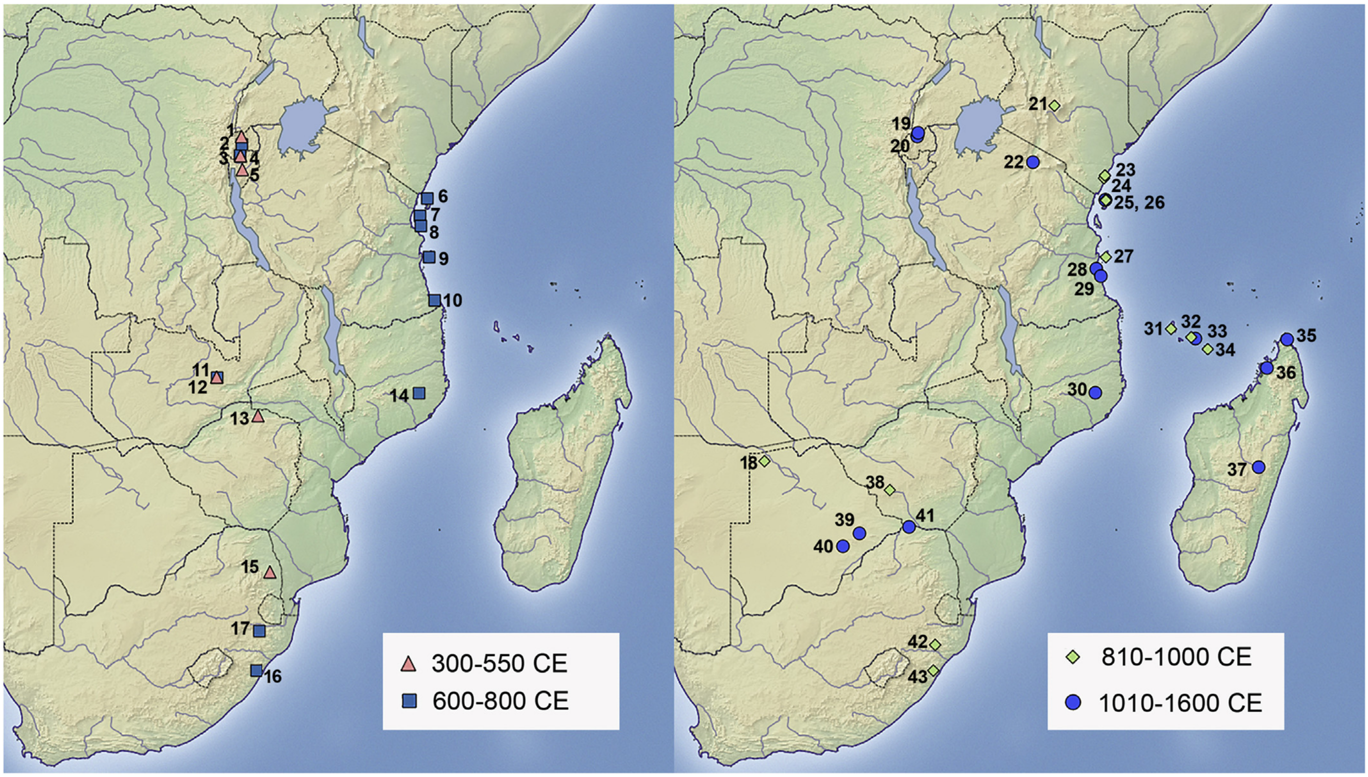

Fig. 3. Map of sites with archaeobotanical evidence for crops from Iron Age eastern and southern Africa. Sites represented in time slices based on median age, and numbered: 1. Kabusanze, 2. Karama, 3. Kabuye II, 4. Kabuye IV, 5. Nyaruyaga II, 6. Pango la Kijiji, 7. Fukuchani, 8. Unguka Ukuu, 9. Ukunju Cave, 10. Mikindani sites, 11. Mondake 1, 12. M'teteshi, 13. Kadzi, 14. Xakota, 15. Silver Leaves, 16. Shongweni (early), 17. Ndondonwane, 18. Nqoma, 19. Nguri Cave, 20. Musanze 2 & 3, 21. Deloraine, 22. Engaruka, 23. Panga ya Saidi & Panga ya Mwandzumari, 24. Mgombani, 25. Tumbe & Kimimba (810–1000 CE), 26. Chwaka & Kaliwa (1020–1600 CE), 27. Juani Primary School, 28. Kilwa, 29. Songo Mnara, 30. Ziwa, 31. M'Bachile, 32. Old Sima, 33. Domoni, 34. Dembeni, 35. Lakaton'i Anja, 36. Mahilaka, 37. Fanongoavana, 38. Leopard's Kopje, 39. Kgaswe, 40. Matlhapaneng, 41. Schroda, 42. Magogo, 43. Shongweni (late).

diversity would have promoted the co-existence of different subsistence groups (Lane, 2004; Shipton et al., 2013). In the coast region, for example, the moist and fertile low coastal plains are suitable for agriculture, the arid high coastal plains support livestock herding, and the tropical forests provide honey and other resources exploited by foragers. Occasional archaeological finds of stone tools typical of the LSA, sometimes in or underlying the lowermost layers of Iron Age sites, hint at the presence of transient foragers on the landscape at, or immediately prior to, the arrival of iron-working groups, though these have rarely been systematically investigated.

However, there are major chronological gaps that hinder our understanding of the relationships among foragers, pastoralists, and farmers. For example, the period of pastoralist expansion through Kenya after c. 1000 BCE is relatively well-documented (e.g., Gifford-Gonzalez, 1998), but later pastoralist sites of the 1st millennium CE, contemporaneous with the spread of agriculture from the Great Lakes to the coast, are less studied (but see Robertshaw, 1990; Siiriäinen et al., 2009; Causey, 2010; Lane, 2011, 2013). This problem becomes especially acute as one moves into central Tanzania, a vast and under-surveyed region implicated in the east- and southward spreads of iron technology and farming (Mapunda, 1995; Schmidt, 1997; Phillipson, 2005).

Like the roles of pastoralists in agricultural transitions, those of foragers have received little consideration, despite ample ethnographic and ethnohistoric evidence for hunter-gatherer agency in exchanges of crops and livestock with farming groups (e.g., Blackburn, 1982; Cronk, 1989; Mutundu, 1999). Furthermore, the roles of forager and pastoralist groups in the spread of crops remain poorly understood. In the Victoria basin, faunal and other data indicate degrees of continuity—despite clear material culture shifts—from Kansyore (LSA) and Elmenteitan (PN) to Urewe (EIA) occupations (Lane et al., 2007; Prendergast, 2008; Ashley, 2010; Dale and Ashley, 2010; Seitsonen, 2010). This suggests that the appearance of Urewe ceramics, while linked to Bantu languages and crops, does not necessarily imply population displacement. Similar conclusions were reached on the nearby Mara plains, where changes in lithic technology and raw materials did not coincide with ceramic shifts (Siiriäinen et al., 2009). The Loita-Mara plains and the Central Rift Valley were populated with specialized pastoralists well before Bantu agropastoralists arrived in the Victoria basin (Marshall, 1990), perhaps explaining why EIA sites are extremely rare in these areas, with evidence of farming appearing several centuries later than in either the Victoria basin or on the coast (Lane, 2013).

2.4. Debates about the introduction of Asian domesticates

Adding yet further complexity to the story of agricultural origins in eastern Africa is the fact that Asian domesticates also reached the region almost certainly largely via sea routes across the Indian Ocean. Two key processes are suggested to have played a role. One is the emergence of early trade connections to the eastern African coast (Casson, 1989; Horton and Middleton, 2000), which linked this region into a global exchange network that moved not just goods but also a variety of biological species, including a range of domesticates around the Indian Ocean (Fuller and Boivin, 2009; Fuller et al., 2011; Boivin et al., 2013, 2014). The other is connections very far afield, to Island Southeast Asia, which were also linked to the migration of Austronesian language-speaking, agriculture-based populations who settled Madagascar and perhaps other islands and parts of the eastern African coast. These trade connections are linked also to the introduction of numerous crops (Crowther et al., 2016b), most notably the key vegetative crops banana, yam, and taro, as well as at least one domestic animal, the chicken (*Gallus gallus*). Core questions surround the timing and routes of arrival of these species. In particular, arguments for extremely precocious arrivals of banana and chicken have met with significant controversy. Chicken, for example, was previously identified at Machaga and Kuumbi Caves on Zanzibar, dating to as early as 3000 BCE (Chami, 2001b, 2009). However, these finds have been called into question (Sutton, 2002; Sinclair, 2007; Robertshaw, 2009), and recent research at Kuumbi was unable to replicate these findings (Shipton et al., 2016). Similarly, banana phytoliths were identified in a core from the Munsa swamp in Uganda dating to as early as the 4th millennium BCE (Lejju et al., 2005, 2006), and in cultural deposits at the mid-first millennium BCE site of Nkang in Cameroon (Mbida et al., 2000, 2001, 2004, 2006). Again, these early finds are problematized by issues of stratigraphic integrity and replicability (Neumann and Hildebrand, 2009). The early banana find in Cameroon has been linked to an arrival via the eastern African coast (De Langhe, 2007).

Perhaps the biggest challenge to early dates for the arrival of Asian domesticates to eastern Africa, however, concerns the lack of evidence for settled agricultural populations in the relevant time frame. Many centuries at least, or in some cases several millennia, separate the earliest Asian species claims from the broadly accepted date for the introduction of agriculture to coastal eastern Africa. This discrepancy has been dealt with by suggestions of economic intensification as part of 'Neolithic' (in the case of the chicken finds) and 'complex forager' (in the case of the banana finds) populations on the coast. De Langhe (2007), for example, has argued that early complex foragers living in the coastal forests of eastern Africa, as well as the Usambara-Pare mountain ranges, would have been sufficiently proficient in plant management to adopt the banana and spread it westwards to the equatorial forests of tropical central and west-central Africa. These are intriguing suggestions that merit serious consideration, especially in light of comparative evidence for indigenous forager intensification in the highlands of New Guinea and elsewhere in Sahul (Denham et al., 2003), but they also rely on scenarios that have to date been inadequately confirmed by zooarchaeological and archaeobotanical studies.

3. Methods

To address these questions concerning the timing and processes by which food production spread to eastern Africa, a large-scale program of archaeological excavation was undertaken in the coastal region to recover high resolution archaeobotanical and zooarchaeological sequences from sites spanning the transition to farming. This work was carried out between 2010 and 2015 as part of the ERC-funded 'Sealinks' project (NB), in collaboration with a British Academy-funded project on the 'Agricultural Transition in Eastern Africa' (AC), and the ERC-funded 'Comparative Pathways to Agriculture' project (COMPAG, DQF). In their broader context, these studies have sought to situate these transformations relative to larger scale processes of Indian Ocean connectivity and the emergence of coastal Swahili culture.

3.1. Environmental setting

The sites investigated by the Sealinks Project that we discuss in this paper are located in the region stretching from the coastal hinterland of Kenya to central Tanzania, including the offshore islands of Zanzibar and Mafia (Fig. 2). This area is characterized by the Zanzibar-Inhambane vegetational mosaic, which includes mangroves, swamps, thickets, and woodlands (Burgess and Clarke, 2000). The mainland coastal and hinterland areas are marked by diverse landscapes, in some areas stretching from a low coastal plain to higher altitude woodlands, others marked by continuous low plain. The coast is cut by several important deltas, including the Tana and Rufiji. By contrast, the offshore islands tend to have sparse vegetation due to thin soils overlying coral rag, though patches of moist tropical forest occur. Such forests, which are also found along the mainland coast, are likely remnants of what was once a much more widespread vegetation zone that stretched along the whole eastern African seaboard, and are today considered hotspots of global biodiversity. However, a general lack of paleoecological data for much of this region (with some notable exceptions, e.g, Punwong et al., 2013a, Punwong et al., 2013b and Punwong et al., 2013c for Zanzibar and the Rufiji delta, and Ekblom et al., 2014 for coastal Mozambique), combined with significant human modification for at least a millennium, renders it difficult to reconstruct past vegetation at any scale.

3.2. Sites and methodology

Our fieldwork strategy involved returning to sites that had been previously excavated and were known to contain rich archaeological sequences spanning the farming transition, including the LSA, EIA, and Middle Iron Age (MIA) periods. While a total of 15 sites have been excavated in these campaigns, some of our analyses are ongoing; we therefore focus here on the results from eleven sites (see Fig. 2) where datasets are more complete. These include five large limestone caves or rockshelters, four of which contain both LSA and MIA occupation horizons: Panga ya Saidi, Panga ya Mwandzumari, and Panga ya Mizigo on the Nyali Coast, Kilifi County, Kenya, and Kuumbi Cave on Zanzibar, Tanzania; the fifth, Ukunju Cave on Juani Island in the Mafia Archipelago, Tanzania, was only occupied from the MIA onwards. The remaining six sites are all open-air villages. Three date to the EIA: Kwa Kipoko in the Kilifi coastal hinterland, Limbo in the central Tanzanian coastal hinterland, and Juani Primary School on Juani Island; while Mgombani (also in Kilifi) is transitional between the EIA and MIA. Fukuchani and Unguja Ukuu on Zanzibar are MIA, and Juani Primary School also has a MIA component. These sites are all characterized by wattle-and-daub architecture, diagnostic Kwale (EIA) and/or Early Tana Tradition (MIA) ceramics, and evidence of iron-working such as slag and tuyères. Notably, Unguja Ukuu was a major Indian Ocean port that covered some 17 ha at its zenith in the late first millennium CE (Juma, 2004). For publications discussing our work at some of these sites, see Helm et al. (2012); Shipton et al. (2013); Crowther et al. (2014); Kourampas et al. (2015); Crowther et al. (2016a, 2016b); Prendergast et al. (2016); Shipton et al. (2016); Prendergast et al., (in press). In our discussion of these data we also draw on findings from sites elsewhere on the island, coast, and coastal hinterland and, more broadly, from Urewe sites in the Victoria basin, Lelesu sites in northern Tanzania, and late Elmenteitan and PIA sites of central and southern Kenya.

Our excavations consisted of mainly one or two trenches of between 2 and 9 m^2 in size at each site. Where possible, areas with known stratigraphic integrity and deep midden deposits were targeted based on prior studies at the sites. Bulk sediment samples were collected from each major stratigraphic context and processed using bucket flotation to collect charred botanical assemblages using 0.3 mm mesh bags. Sediment samples for starch and phytolith analysis were also collected to test for the presence of vegetative crops such as banana, taro, and yam, but only a selection of these have been analyzed to date, from Panga ya Saidi, Mgombani (Smith, 2012), and Unguja Ukuu (Le Moyne, 2016). Further details on the excavation, recovery, and identification methods used in our study are described elsewhere (Helm et al., 2012; Crowther et al., 2014, 2016a, 2016b; Prendergast et al., 2016).

A key part of our archaeobotanical methodology included obtaining direct AMS dates on crop remains to establish a secure absolute chronology for the introduction of agriculture to the east coast region. Prior to our study, only three radiocarbon dates had been obtained on crops in this region (Walshaw, 2015), with chronological reconstructions relying instead on associated radiocarbon dates, usually on unidentified charcoal (which can potentially bias dates owing to the old wood effect), or indirect ceramic typologies. To this we add a suite of 32 new direct crop dates from five sites (Table 2). Our analysis has demonstrated that the strategy of directly dating crops is critical given that the coastal environment in which many of the sites are situated is highly dynamic, with small seeds at risk of moving post-depositionally through sandy sediments from later into earlier horizons (see Crowther et al., 2016a for discussion of these issues at the Juani Primary School site).

4. Results and discussion

Our combined archaeobotanical, zooarchaeological, and material cultural datasets support a very complex scenario of farming arrivals on the eastern African coast. Our study demonstrates no clear, consistent, or straightforward association between standard cultural entities (e.g., LSA, EIA, MIA) and subsistence patterns. However, despite our efforts to target sites covering a wide temporal span, of the three EIA sites excavated, only Juani Primary School yielded assemblages that, although still quite small, enable us to begin addressing questions concerning the possible role of domesticates in the EIA economy. At both Limbo and Kwa Kipoko, faunal preservation was extremely poor, and our studies of the botanical assemblages from these two sites were unfortunately curtailed by their inadvertent loss by an international courier. The only other site in our sample with a significant EIA component, Mgombani, is transitional between the EIA and MIA and has thus far failed to produce any AMS dates on crops earlier than the 7th–8th century CE (MIA). As such, despite the critical importance of this period for models of early farming expansion on the east coast, major gaps in the EIA subsistence records remain largely unaddressed. Nonetheless, our data permit important insights into eastern Africa's transition to agriculture, and help challenge orthodox models of cultural replacement, despite their limitations.

The first clear and strong signal of farming in our eastern African coastal dataset occurs in sites dating to the MIA (Fig. 3). Here we see the presence of all three major native African cereals along with cowpea and baobab (Fig. 4), as well as livestock such as cattle, sheep, and goat by the 7th century CE. While this broadly concurs with the (albeit limited) pre-existing archaeobotanical and zooarchaeological evidence (Fig. 3; also reviewed in Boivin et al., 2013), a number of potentially significant patterns stand out from our expanded dataset concerning the timing, tempo, and processes involved in the farming transition. Firstly, it is apparent that crops and livestock did not spread to the coast in a tight 'Iron Age package'. Rather, sites show wide temporal and spatial variation in the importance of domesticates relative to other foods (marine fauna, wild plants and animals), as well as to each another. Notable among the crop data is the near absence of finger millet from the offshore islands (see also Walshaw, 2015) compared to its consistent

Table 2
Accelerator mass spectrometry (AMS) radiocarbon dates on crop remains from our sites, shown in stratigraphic order from uppermost (top) to lowermost (bottom) contexts per trench. Dates were calibrated to 2σ (95.4% confidence) with the program OxCal v.4.2.4 (Bronk Ramsey, 2009) using mixed IntCal13/SHCal13 (Hogg et al., 2013; Reimer et al., 2013) (70:30) calibration curves to account for the effects of the inter-tropical convergence zone (see Crowther et al., 2016b). † = sample duplicate.

Site	Trench	Context	Material, taxon	Laboratory no.	^{14}C date BP	cal CE
Panga ya Saidi	PYS10-01	103	Charred seed, *Sorghum bicolor*	OxA-29285	1212 ± 23	770–950
		103	Charred seed, *Adansonia digitata*	OxA-26775†	522 ± 25	1405–1450
		103	Charred seed, *Adansonia digitata*	OxA-26776†	536 ± 24	1400–1445
Mgombani	MGB10-01	101	Charred seed, *Pennisetum glaucum*	OxA-27099	1184 ± 26	775–980
		101	Charred seed, *Pennisetum glaucum*	OxA-27100	1179 ± 25	775–985
		105	Charred seed, *Sorghum bicolor*	OxA-29276	1217 ± 29	765–960
Unguja Ukuu	UU11	002	Charred seed, *Adansonia digitata*	OxA-29286	1066 ± 23	980–1030
		004	Charred seed, *Adansonia digitata*	OxA-27517	1178 ± 25	775–985
		006	Charred seed, *Sorghum bicolor*	OxA-X-2554-12	1266 ± 35	680–885
		007	Charred seed, *Pennisetum glaucum*	OxA-27541	1310 ± 31	660–860
		010	Charred seed, *Vigna radiata*	OxA-27660	1305 ± 28	665–855
		012	Charred seed, *Pennisetum glaucum*	OxA-X-2507-17	1403 ± 28	605–760
		012	Charred seed, *Sorghum bicolor*	OxA-29287	1318 ± 23	675–770
		013	Charred seed, *Adansonia digitata*	OxA-27516	1372 ± 25	645–765
		013	Charred seed, *Sorghum bicolor*	OxA-28657	1390 ± 25	640–760
		013	Charred seed, *Sorghum bicolor*	OxA-29277	1342 ± 24	660–770
		014	Charred seed, *Vigna radiata*	OxA-27515	1280 ± 26	680–875
		017	Charred seed, *Sorghum bicolor*	OxA-28656	1367 ± 26	645–765
	UU14	1404	Charred seed, *Oryza sativa*	OxA-27520	1151 ± 26	885–990
		1417	Charred seed, *Sorghum bicolor*	OxA-27518†	1244 ± 27	715–890
		1417	Charred seed, *Sorghum bicolor*	OxA-27519†	1287 ± 25	675–860
		1417	Charred seed, *Sorghum bicolor*	OxA-27698†	1226 ± 25	765–895
		1420	Charred seed, *Sorghum bicolor*	OxA-29278	1317 ± 24	670–770
		1436	Charred seed, *Oryza sativa*	OxA-28189	1265 ± 23	685–880
		1439	Charred seed, *Sorghum bicolor*	OxA-29279	1232 ± 26	765–895
		1439	Charred seed, *Triticum* sp.	OxA-29288	1305 ± 24	670–835
		1442	Charred seed, *Sorghum bicolor*	OxA-28658	1314 ± 26	665–775
		1445	Charred seed, *Oryza sativa*	OxA-27595	1245 ± 22	765–890
	UU15	1556	Charred seed, *Vigna unguiculata*	OxA-30955	1265 ± 45	675–890
Juani Primary School	JS12-05	503	Charred seed, *Vigna* cf. *unguiculata*	Wk-40939	1173 ± 20	875–980
		505	Charred seed, *Vigna* cf. *unguiculata*	Wk-40938	1184 ± 21	775–975
		505	Charred seed, *Vigna* sp.	Wk-40937	1181 ± 20	775–975

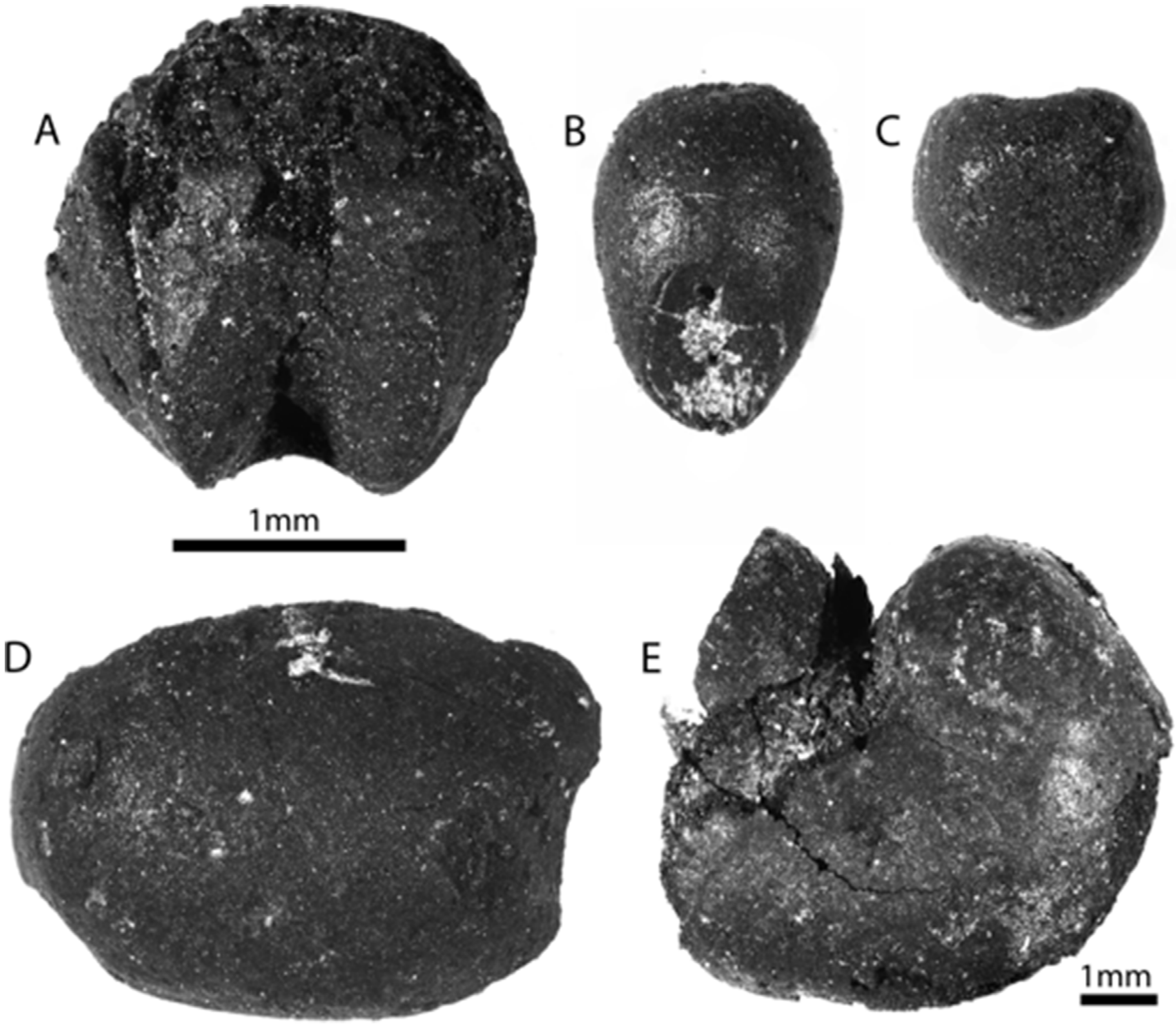

Fig. 4. Examples of crop remains recovered from the sites. A. *Sorghum bicolor* (sorghum), B. *Pennisetum glaucum* (pearl millet), and C. *Eleusine coracana* (finger millet) from Panga ya Saidi. D. *Vigna unguiculata* (cowpea) from Unguka Ukuu. E. *Adansonia digitata* (baobab) from Juani Primary School. (Scale bar in A applies to A–D).

presence at our hinterland sites as well as sites in the interior (Ambrose et al., 1984; Giblin and Fuller, 2011), which are more ecologically suitable for finger millet cultivation. Secondly, farming does not replace foraging when it is introduced. Indeed, well into the MIA period, fishing, and the hunting and trapping of wild fauna, continue to have economic significance, even at major trading settlements such as Unguja Ukuu. Thirdly, our sites in southeastern Kenya suggest that there was a protracted period of interaction between Iron Age groups and forager populations during which domesticated plants (among other items of material culture) were exchanged. These findings challenge linear models for the rapid replacement of foragers by farmers during the agricultural transition, supporting more recent models arguing that people practicing both strategies coexisted in eastern Africa for centuries (e.g., Lane, 2004; Kusimba and Kusimba, 2005; Lane, 2015 among others; see Clist, 2006 for similar discussion in Central Africa). Fourthly, while our evidence for pre-MIA subsistence is still extremely limited and patchy, we have yet to see clear evidence for an early arrival of Asian domesticates on the east coast through Indian Ocean trade. In fact, even in the MIA, when we have stronger evidence for the arrival of foreign taxa such as Asian rice and chicken, there appears to be limited uptake of these beyond trading sites on the offshore islands. We use these four key points to frame our discussion below, drawing on comparisons where relevant with data from sites in the Great Lakes and Rift Valley regions, before briefly elaborating on the methodological issues flagged above concerning preservation and the logistics of recovery, which present ongoing challenges for documenting the expansion of farming in our study region.

4.1. Early Iron Age farming: absence of evidence or evidence of absence?

As we discuss above, our subsistence reconstructions at coastal EIA sites were hindered by a combination of poor preservation as well as accidental sample loss. Faunal preservation at both Kwa Kipoko and Limbo was poor, with just two nonhuman specimens at Kwa Kipoko and none at Limbo. This preservation pattern is one that is repeated at many EIA sites across the coastal region, with nearly all excavations reporting minimal faunal preservation (Table 3), a factor potentially linked to the iron-rich but acidic laterite soils that were the preferred locations of early iron-working settlements. The Juani Primary School site in the Mafia archipelago, however, proved to be an important exception (Crowther et al., 2016a). Here, comparatively abundant faunal remains, dominated by fish and molluscs (Fig. 5), were recovered alongside rich ceramic deposits in the EIA levels. Tetrapods, including terrestrial

Table 3
Non-human faunal remains at coastal and hinterland sites with Early Iron Age material culture (excludes surface sites). NISP = Number of Identified Specimens.

Site	Location	Faunal preservation	References
Kwa Kipoko	SE Kenyan coastal hinterland	NISP = 2	This study
Mgombani	SE Kenyan coastal hinterland	NISP = 42	Mudida in Helm, 2000
Kwale	SE Kenyan coastal hinterland	not preserved	Soper, 1967
Ziweziwe	Central Tanzanian coast	4 specimens	Chami and Kessy, 1995
Kwale Island	Central Tanzanian coast	"many" "mammals, birds, fish"	Chami and Msemwa, 1997; Chami, 1998
Limbo	Central Tanzanian coast	not preserved	Chami, 1988, 1992; this study
Misasa	Central Tanzanian coast	5 specimens	Chami, 1994
Kivinja	Central Tanzanian coast	not mentioned	Chami and Msemwa, 1997; Chami, 1998
Mkukutu-Kibiti	Central Tanzanian coast	not preserved	Chami, 2001a,b
Mwangia	Central Tanzanian coast	1 specimen	Chami and Mapunda, 1998
Misimbo	Central Tanzanian coast	not mentioned	Chami, 2001a,b
Mlongo	Mafia archipelago	not mentioned	Chami, 1999
Juani School	Mafia archipelago	NISP = 27; 387	Chami, 2004; Crowther et al., 2016a

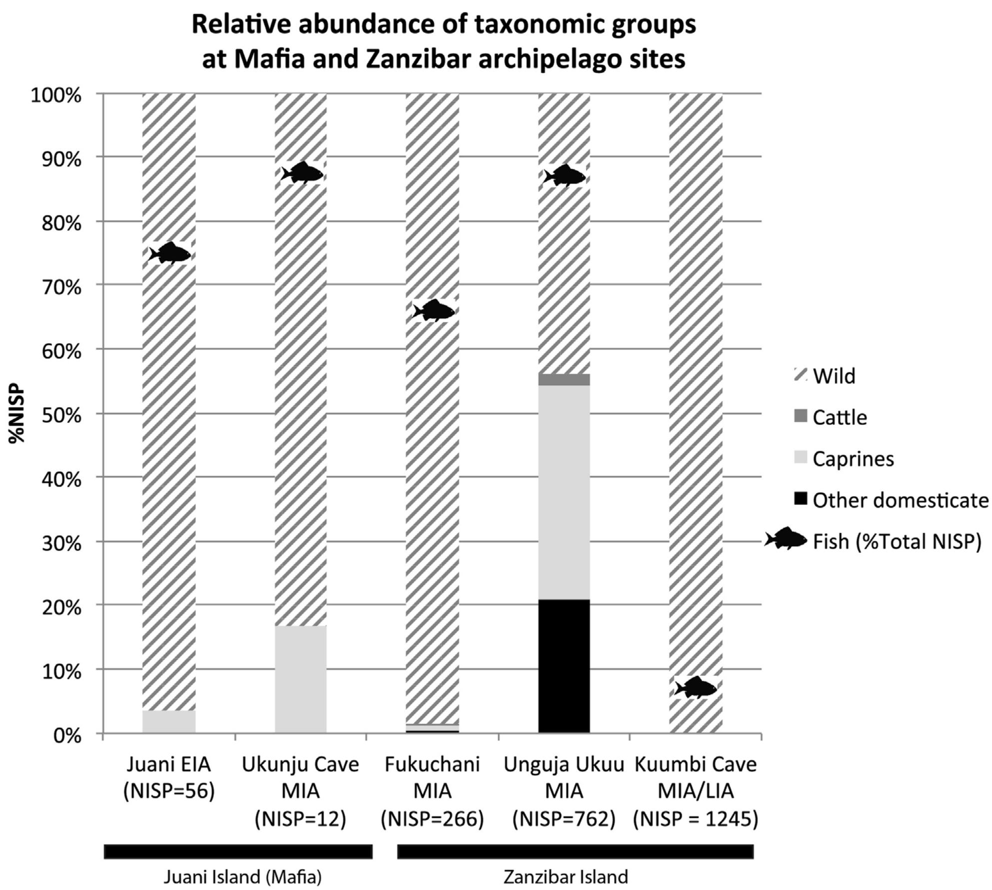

Fig. 5. Relative abundance of fish out of total vertebrate NISP (indicated by location of fish icon along y-axis), and wild and domestic taxa out of total tetrapod NISP (indicated by bar graph). The latter dataset excludes microfauna (e.g., bats, rodents, and small reptiles), human remains, and specimens identified to categories (e.g. Small Mammal, Bird) that did not permit distinction between wild and domestic taxa. 'Caprines' at Juani Primary School are tentative identifications.

mammals, birds, and marine turtles are rare (Number of Identified Specimens or NISP = 94), as was the case in earlier excavations at the same site (Chami, 2004). This likely reflects choices made by the site occupants, as it is unclear what conditions would produce differentially poor preservation of mammalian remains. The only possible domestic animal remains consist of a single caprine tooth and a caprine-sized bone whose identities are uncertain, while the remainder of the assemblage indicates hunting or trapping of small game such as duiker and capture of marine turtles, alongside the main activities of fishing and shellfish collection.

Likewise, despite intensive archaeobotanical sampling at the Juani Primary School site (over 1000 L floated from the EIA layers alone), only a very small quantity of crop remains was recovered. These included sorghum, probable cowpea, and baobab (Table 4). Although some of these remains were from the uppermost EIA levels, direct AMS dating of a sample of three returned MIA dates, suggesting they had shifted down the stratigraphic profile from the immediately overlying MIA contexts. Taking a cautious approach, therefore, we infer that the few other undated crop remains from these upper EIA levels are also likely to be MIA in date, meaning that the site has yet to produce any convincing evidence for EIA agriculture. Elsewhere (Crowther et al., 2016a) we argue that this

Table 4
Summary of archaeobotanical crop data for eastern Africa, including other published studies (shaded). Remains represent charred seeds unless indicated otherwise. X = present but not quantified. PYS = Panga ya Saidi, SC = Panga ya Mwandzumari, MGB = Mgombani, UU = Unguja Ukuu (*includes a lump of charred sorghum grains recovered from a hearth, given an estimated count of 100 grains), FK = Fukuchani, JS = Juani Primary School, PU = Ukunju Cave (this study). DEL = Deloraine Farm (Ambrose et al., 1984). KBS = Kabusanze, KRM = Karama, MSZ = Musanze II and III (Giblin and Fuller, 2011). MKD = Mikindani (Pawlowicz, 2011). TMB = Tumbe, KMB = Kimimba, CWK = Chwaka, KAL = Kaliwa (Walshaw, 2015). KWA = Kilwa (Chittick, 1974).

Site		PYS	SC	MGB	FK	UU	JS	PU	KBS	KRM	MSZ	NGC	DEL	TMB	KMB	CWK	KAL	KWA	MKD
Period		MIA-LIA	MIA-LIA	EIA–MIA	MIA	MIA	MIA	MIA	EIA	MIA	LIA	LIA	MIA	MIA	MIA	LIA	LIA	LIA	EIA–MIA
Number of samples analyzed:		11	8	22	12	49	4	9	7	3	8	5	1	23	17	34	11	n/a	n/a
Total sample volume (L):		364	240	664	323	2374	240	204	150	36	90	60	25	262.6	242	341.5	111	n/a	231
Pearl millet	*Pennisetum glaucum*	2		266		30		3	1					175	1		4		22
	Pennisetum sp.							1								10			
	cf. *Pennisetum glaucum*				1	10		1						106		10			
	Pennisetum glaucum, chaff													13					
Sorghum	*Sorghum bicolor*	5		74		135*	1		1					3		5		X	2
	Sorghum cf. *bicolor*					1													
	cf. *Sorghum bicolor*	9			3	5													
	Sorghum sp., chaff			198		71		6								1			
Finger millet	*Eleusine coracana*	1		30						4	18	8	1	1		1	1		
Cowpea	*Vigna unguiculata*					1													
	Vigna cf. *unguiculata*						3	1	5										
Baobab	*Adansonia digitata*	3		1		2	3	1											1
	Adansonia digitata, testa frags	X	X	7		X													
	cf. *Adansonia digitata*, testa frags	X		2	1		4	7											
Hyacinth bean	cf. *Lablab* sp.											1							
Asian rice	*Oryza sativa*					16								4		15146	21		1
	cf. *Oryza sativa*					1													
	Oryza sativa, chaff													20		5455	76		
Mungbean	*Vigna radiata*					3										4			
Sesame	*Sesamum* cf. *indicum*													1					
Wheat	*Triticum* sp.					2										1			
	cf. *Triticum*													3					2
Pea	*Pisum* sp.															43			
	cf. *Pisum sativum*																		7
Lentil	*Len culinaris*					1													
Coconut	*Cocos nucifera*, endocarp frags					X								135	41				
Legume	*Vigna* sp.						7	1						6		2			
	cf. *Vigna* sp.			2		1													
Cotton	*Gossypium* sp.															591	31		1
	cf. *Gossypium* sp., testa frags							5											
	Gossypium sp., funicular caps							3						2					

subsistence pattern represents a maritime adaptation of EIA farmers to the island environment, one that is later subsumed by a more mixed herding and farming subsistence system that continues to include large contributions from marine resources.

While comparative EIA data from sites on the mainland is still patchy, positive evidence for crops (discussed in Section 2.3 above) is available from sites in Rwanda (Giblin and Fuller, 2011) and on the southern coast of Tanzania (Pawlowicz, 2011) (Fig. 3), suggesting that at least some EIA groups had an agricultural component to their economy. The apparent absence of crops and near absence of livestock in the EIA levels at the Juani Primary School nonetheless forces us to re-evaluate the presumed importance of agriculture in the context of so-called Bantu expansion, showing instead the fluid nature of subsistence as these groups moved onto the islands and responded to new opportunities in their maritime environment. This scenario also raises the question of whether the maritime adaptation of 'early farming' groups as they moved onto the coast and islands was more widespread. Of relevance are a series of EIA shell midden sites that have been found along the coast as far south as southern Mozambique (Morais, 1988; Sinclair, 1991; Sinclair et al., 1993). These sites, which contain EIA Matola pottery (a variant of Kwale), broadly overlap in date with Kwale sites, despite being located some 1700 km to the south. Significantly, zooarchaeological studies show that these EIA coastal midden sites also lacked domesticated livestock, though, again, poor preservation cannot be ruled out as a contributing factor (Bousman, 1998). Could a similar maritime adaptation have enabled the rapid dispersal of EIA peoples into southern Africa? If these groups did move as quickly as the radiocarbon dates suggest, then mobility would certainly have been facilitated by a reduced reliance on food production during their initial expansion—particularly if this expansion involved a seafaring component, as suggested by the colonisation of Juani Island and perhaps implied by the rapid coastal movement to the south. Without further subsistence data from these and other coastal EIA sites, it is difficult to comment further on these hypotheses. They nonetheless remain intriguing possibilities, and ones that highlight the ambiguity of bounded terms such as 'Iron Age farmer', particularly when applied on the basis of material culture rather than systematically collected subsistence evidence.

4.2. Middle Iron Age evidence shows asynchronous transitions to mixed farming

For the present study, the majority of data relating to both crop cultivation and animal herding derives from the MIA (c. 7th–10th centuries CE). This period is characterized by the development of cosmopolitan, pre-urban, proto-Swahili society on the coast, and a major florescence in Indian Ocean trade in which coastal Iron Age communities established themselves as merchant middlemen (e.g., Horton and Middleton, 2000; LaViolette, 2008). During this period, we see evidence for all major native African crops and livestock on the coast, as well as some non-native species introduced through trade (discussed further in Section 4.4), but we note the wide spatial and temporal variability in their appearance and overall importance to local subsistence. At many sites, subsistence in this

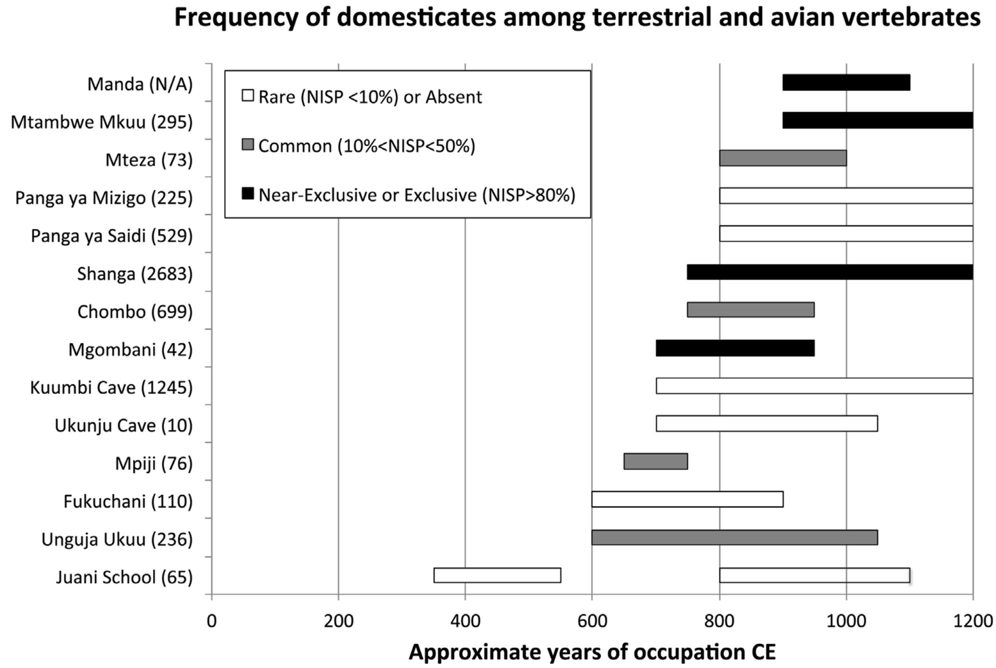

Fig. 6. Comparison of Sealinks Project sites discussed in the text with other coast and hinterland sites. The dataset for each site (NISP in parentheses) excludes fish and other aquatic animals such as sea turtle, as well as microfauna (e.g., bats, rodents, and small reptiles), human remains, and specimens identified to categories (e.g., Small Mammal, Bird) that did not permit distinction between wild and domestic taxa. For multi-period cave sites (Panga ya Mizigo, Panga ya Saidi, and Kuumbi Cave), only the Iron Age levels are shown. References for non-Sealinks sites: Manda (Chittick, 1984), Mtambwe Mkuu (Horton and Mudida, 2017), Shanga (Mudida and Horton, 1996), Mpiji (Chami, 1994); Mteza/Chombo/Mgombani (Helm, 2000).

period continued to involve significant hunting/trapping and fishing components, pointing to the ongoing importance of wild resources to local diets (Fig. 6).

An excellent example of this mixed subsistence strategy is the 7th–9th century site of Fukuchani on Zanzibar, where the ratios of marine, wild, and domestic fauna are nearly identical to those of the EIA Juani Primary School site discussed above (Fig. 5), despite botanical evidence, including remains of sorghum and pearl millet, suggesting the presence of food producers. The occupants of Fukuchani devoted themselves largely to fishing; fish comprise two-thirds of NISP (Prendergast et al., in press), though it should be stressed that fish NISP values tend to be inflated by the greater number of skeletal elements. The occupants also had access to a wide range of game on Zanzibar, exploiting small bovids, bushpig, hyrax, and giant pouched rat, plus marine resources such as sea turtle and a diverse array of fish. The social significance of wild fauna is particularly evident from a cache of 13 bovid metatarsals, with this type of skeletal element argued to have held symbolic meaning at 1st millennium CE sites in southeastern Congo (de Maret, 2016). Domestic caprines, cattle, and chicken are also present at Fukuchani, as is the Asian black rat, all in very low numbers.

In contrast with Fukuchani and Juani, the occupants of the larger and more 'urban' site of Unguja Ukuu, also on Zanzibar, relied more heavily on domestic fauna, while continuing to hunt, trap, and fish; in fact, fish are more dominant than at Fukuchani, constituting 87% of NISP (Prendergast et al., in press). While the range of wild taxa exploited is broadly similar, the proportion of wild fauna is lower at Unguja Ukuu compared with Fukuchani (Fig. 5). The focus of the domestic economy is caprine (mainly goat) herding, though cattle are also present and in fact the Unguja Ukuu cattle remains may be amongst the earliest on the Swahili coast. There is a notable shift between the earlier (c. 650–800 CE) and later (c. 800–1050 CE) occupations at Unguja Ukuu, with chicken, black rat, and domestic cat all becoming more abundant in the later phase.

Kuumbi Cave, in the southeast of Zanzibar, offers an interesting contrast to these sites and presents parallels to the forager-food producer mosaics of the Rift Valley and adjacent areas, where rockshelters frequently have ceramics associated with food producers, but entirely or mostly wild faunal assemblages (reviewed by Prendergast, 2011). The upper deposits of Kuumbi Cave bear MIA ceramics similar to those seen at Unguja Ukuu and Fukuchani, yet unlike these sites – and in contrast with prior reports (Chami, 2009) – our excavations did not identify a single domestic animal (Prendergast et al., 2016; Shipton et al., 2016). One possible scenario is that Kuumbi Cave was occupied by foragers who, through some form of exchange or clientship relationship, either obtained or produced the ceramics themselves; however other interpretations are possible, including special-purpose use of the site by food producers.

These scenarios are also plausible explanations for patterns at other cave sites with MIA material culture and predominantly or exclusively wild fauna, including Ukunju Cave in the Mafia archipelago (where fish were, as at Juani, a key component of the diet), and at Panga ya Saidi and Panga ya Mizigo in the southeastern Kenyan coastal hinterland. As we discuss in Section 4.3 below, previous research in the latter region (Helm, 2000; Helm et al., 2012; Shipton et al., 2013) documented dynamics of forager-food producer interaction from the MIA, largely inferred from material culture but in some cases from detailed faunal analysis (Mudida in Helm, 2000).

The importance of cultivation to the MIA subsistence economy is demonstrated by the ubiquitous presence of domesticated crops at all sites of this period that we have analyzed so far (Table 4). Our earliest pearl millet, sorghum, cowpea, and baobab remains come from the site of Unguja Ukuu, where AMS dates place their presence from the beginning of occupation between c. 650–770 cal CE (Table 2). These are among the earliest direct dates for cultivated plants from anywhere on the eastern Africa coast, and show that the ‘Iron Age’ agricultural package was largely assembled by this time. Finger millet, however, is notably missing from the Unguja Ukuu botanical assemblages, and near absent from any other island site barring a single grain found each at Tumbe, Chwaka, and Kaliwa on Pemba by Walshaw (2015). In contrast, sites such as Mgombani in the Nyali coastal hinterland in Kenya produced some 30 grains (8% crop seed remains), while the nearby cave site of Panga ya Saidi produced one specimen (5% crop seed remains). While this pattern could be the result of either sampling bias or taphonomic factors (cf. Young and Thompson, 1999), one possible reason for the rarity of this crop on the offshore islands could be ecological. All these islands are fairly low-lying, with average elevations below about 30 m, yet most successful finger millet cultivation world-wide is found between 500 and 2400 m elevation (National Research Council, 1996). Even today, these islands—and indeed the whole coastal region—occur outside the range of modern finger millet cultivation (Hilu and de Wet, 1976), which is restricted to more interior and upland zones of Africa. Archaeological sites in the interior, such as those analyzed by Giblin and Fuller (2011) in Rwanda have also produced finger millet remains (though also not before c. 750 CE). This is in addition to the single finding of a grain at Deloraine, dated to c. 800 CE (Ambrose et al., 1984). It seems likely then that such ecological constraints may have caused great spatial variability in both the spread and relative importance of such crops long considered integral to the ‘Bantu package’.

While our archaeobotanical analyses have still to identify the majority of non-crop remains often found in our assemblages, it is notable that a range of wild taxa are present. These include various wild grass seeds such as *Brachiaria* sp., *Echinochloa* sp., and *Panicum* sp. (though some may be arable weeds rather than subsistence plants), *Ficus* sp., nut endocarp fragments, and occasional parenchyma tissue (see also Walshaw, 2015). These findings suggest that wild plant foods still played an important role in early farming diets. Interestingly, archaeobotanical records from early farming sites in Zimbabwe, dating from c. 500–900 CE, were almost entirely dominated by wild plants, though small quantities of domesticated finger millet and sorghum were also found (Jonsson, 1998). Taken together, these integrated botanical and faunal datasets from across eastern Africa chart a slow transition to economies reliant on domesticated taxa; a pattern that is also seen in many other regions of the world, including East Asia, Southeast Asia, and margins of Europe (Fuller and Qin, 2010; Kirlies et al., 2011; Stevens and Fuller, 2012; Castillo et al., 2017).

4.3. Forager-food producer interactions: did eastern African foragers adopt farming?

Our excavations at a range of rockshelter and open air sites in the coastal uplands of the Nyali region, Kenya, document the emergence and intensification of trade and interactions between local foragers and early farming communities beginning in the late first millennium CE (Helm et al., 2012; Shipton et al., 2013). Sequences from three rockshelter sites excavated by the Sealinks Project show long and continuous hunter-gatherer LSA occupation of the coast region since at least the early Holocene. Cultural assemblages from these sites include dense concentrations of lithics as well as pierced *Conus* and Cypraeae shell beads in the lower layers. In the upper layers, MIA–LIA ceramics, including diagnostic early to late TT/TIW ware, as well as glass beads, appear alongside the LSA assemblages. Although flotation of sediments from Panga ya Mwandzumari failed to produce any identifiable crop remains other than baobab seed fragments, at Panga ya Saidi, small quantities of sorghum, pearl millet, finger millet and baobab were also found in these upper ceramic-bearing layers (Table 4; though see our comment below on the stratigraphic displacement of the finger millet). The faunal assemblages from two sites, Panga ya Saidi and Panga ya Mizigo, however, show no unequivocal evidence of pre-modern domesticated livestock. Continuity in lithic technology from the pre-ceramic to ceramic layers suggests the ongoing occupation of these sites by local hunting-foraging populations from the LSA into the farming period, with ceramics, crops and glass beads most likely acquired through contact with neighboring farming communities engaged in trans-oceanic trade or linked into associated regional trade networks.

What stands out across these rockshelter sites is the absence of EIA Kwale ceramics in their stratified deposits. In all cases, the ceramic transition occurs during the MIA and is supported by direct AMS dates on the crops showing their appearance from the 7/8th century CE onwards. While a few fragments of baobab seed and a single finger millet grain were found in the immediate pre-ceramic levels at Panga ya Saidi, direct dating has not been undertaken to establish the age of these samples owing to their small size and we consider it likely that these have been stratigraphically displaced. The evidence appears to indicate a delay in interaction between foraging and farming communities on the Nyali Coast until the MIA, even though there are several EIA sites (including Kwa Kipoko, discussed above) in the vicinity. While more excavations and dating of EIA sites are needed to establish that this pattern is not merely a sampling issue, it does raise the possibility that these communities may have co-existed on the landscape for several centuries before entering into archaeologically-visible trade, exchange and other relationships. The expansion of farming populations in the MIA, as indicated by an increase in sites on the Nyali Coast at this time, would have encouraged increased contact. That this also coincides with the main period of Indian Ocean trade in coastal eastern Africa is significant, given that many of the raw materials sought for trade by coastal merchants, such as ivory, animal skins, and copal resin, would have been supplied by forager and pastoralist groups in hinterland forests and the interior (S. Kusimba, 2003; Kusimba and Kusimba, 2005). The presence of glass beads at the rockshelter sites examined here attests to the movement of Indian Ocean goods through these local networks. The intensification of long-distance Indian Ocean trading networks in the MIA thereby appears to have potentially encouraged and supported the development of local trade linkages that brought foraging and farming communities into increasing contact over an extended period of time.

Whether foragers became farmers as part of this process, or only acquired crops from farmers through trade, is unclear on present evidence. Current mitochondrial DNA evidence from contemporary populations points to a degree of intermarriage between Bantu men and local non-Bantu women during the farming expansion period (Pakendorf et al., 2011; Heyer and Rocha, 2013). From an archaeological point of view, radiocarbon dates on crop remains from the uppermost levels of Panga ya Saidi (Table 2) suggest that these stone-tool using forager groups maintained a distinct presence on the landscape until at least the early 15th century CE, but after that, use of the caves appears to have shifted to a more intermittent ritual use of the type associated with recent Mijikenda communities. We are uncertain if this change reflects a depopulation of the coast by foragers or their ultimate integration by farming communities. Kusimba et al. (2005) argue that similar cultural mosaics in the neighboring Tsavo region collapsed around the end of the 15th century CE, probably as a result of a decline in trade as well as drought and disease brought about by climate change and other disruptions. It seems possible that parallel factors may have affected mosaic communities on the coast, perhaps forcing or compelling foragers to leave the region.

Comparative insights into the dynamics of coastal mosaics also come from the eastern side of Lake Victoria (Nyanza province, Kenya), where a half-century of research has illuminated the complex spatial and chronological overlaps between foragers and food producers during the time frame of the Bantu expansion (reviewed by Lane, 2004; Stahl, 2004; Kusimba and Kusimba, 2005; see also Reid, 1996). As on the coast, EIA-period faunal preservation is poor, except at the sites of Usenge 3, Wadh Lang'o, and Gogo Falls (Robertshaw, 1991; Lane et al., 2007; Prendergast, 2010); the latter is the only Nyanza site with botanical data, which did not include crops (Wetterstrom, 1991a). Rather, as on the coast, farming has been largely inferred from the presence of ceramics as a *fossile directeur* for the Bantu expansion. Urewe ceramics appear in Nyanza in the 3rd–4th centuries CE, at least seven centuries after their occurrence west of the lake (Lane, 2004; Ashley, 2005; Lane et al., 2006), a delay that might be attributable to the presence of well-established foraging and herding communities. Kansyore ceramic-using fisher-foragers had been creating rockshelter deposits, shell middens, and open sites in Nyanza since at least c. 6000 BCE, with later Kansyore open and midden sites having some evidence for livestock (Karega-Munene, 2002; Lane et al., 2007; Prendergast, 2010; Ashley and Grillo, 2015). It is possible that at some multiperiod sites with Urewe ceramics, such as sites around Lake Saru in northern Nyanza (Ashley, 2005; Dale and Ashley, 2010), the more recent occupants were foraging descendants of these earlier Kansyore groups who obtained or manufactured Urewe ceramics. However, as with the coastal caves, understanding such fisher-forager-farmer relationships is thwarted by post-depositional mixing, a lack of secure dates, few faunal studies and even less botanical data.

While in northern Nyanza, Urewe ceramics often overlie or appear near earlier Kansyore sites (Lane et al., 2006; Dale and Ashley, 2010), in southern Nyanza, intervening PN-era deposits occur. At Gogo Falls and Wadh Lang'o, Kansyore occupations are overlain by livestock remains, ash interpreted as burnt dung, and Elmenteitan ceramics (Robertshaw, 1991; Karega-Munene, 2002; Lane et al., 2007; Prendergast, 2008). Technological and raw material discontinuities suggest the arrival of new populations (Seitsonen, 2010). Unlike their specialized pastoralist counterparts on the Mara plains, however, these Elmenteitan occupants also hunted and fished (Marshall and Stewart, 1994; Prendergast, 2008), indicating some continuity with Kansyore foraging-fishing traditions. Such dietary diversity was long seen as a response to ecological constraints, but isotopic work has unraveled this theory by suggesting that the area may have had ample grasslands for livestock grazing, forcing consideration of other, perhaps social, factors (Chritz et al., 2015). Parallels may be drawn to the continued reliance on wild and marine resources on the coast, which may in fact reflect EIA and MIA farmers' cultural choices. Unlike the sharp technological discontinuities from Kansyore to Elmenteitan contexts, the Elmenteitan to Urewe transitions at Gogo Falls and Wadh Lang'o are marked by continuity in lithic technology, hunting, and fishing (though post-depositional mixing is a concern at Gogo Falls) (Robertshaw, 1991; Karega-Munene, 2002; Prendergast, 2008; Seitsonen, 2010). The southern Nyanza sites thereby suggest that in-migrating Bantu farmers would have formed relationships—possibly mutually beneficial ones—with culturally distinct fisher-forager and herder groups, rather than simply displacing or assimilating them.

On the Mara plains, where Elmenteitan sites are dominated by livestock and where limited Iron Age finds have been reported (Robertshaw, 1990; Siiriäinen et al., 2009), crop-for-caprine exchanges between Elmenteitan herders and newly arrived farmers have been proposed (Robertshaw, 1990). This could have been a key mechanism in the spread of farming, as well as a driver of change in herding societies. However, supportive evidence is limited. An early isotopic study showed that, in contrast to that of SPN herders, the Elmenteitan diet included a significant plant component (Ambrose and DeNiro, 1986); yet wild plant exploitation by pastoralists is entirely plausible (Grillo, 2012). Similarly, wild plant exploitation could explain the rare presence of ground stone axes on PN sites (Robertshaw and Collett, 1983; e.g. Prendergast et al., 2013). Archaeobotanical or proxy subsistence data such as ceramic residues are sorely needed to address this issue.

Robertshaw (1990), Bower (1991), and others note shifts in pastoralist economies at the beginning of the first millennium CE, coincident with the EIA. Evidence cited includes the breakdown of long-distance obsidian exchange networks and shifts from specialized herding at SPN Narosura sites to increased reliance on wild game at later SPN (Akira, Marangishu) sites; however, the current state of imprecise dating within the SPN makes any diachronic trend difficult to confirm. If these shifts are genuine, it remains to be determined whether they are in fact responses to the in-migration of Bantu farmers. Evidence for farming and iron-working in the Rift Valley remains virtually absent until the early second millennium CE, with a few exceptions. These include the c. 800 CE site of Deloraine Farm near Lake Nakuru, Kenya (Ambrose et al., 1984; Sutton, 1993), and the appearance of putatively earlier but poorly-dated Lelesu ceramics (arguably a variant of Kwale ware) in northern and central Tanzania (Kohl-Larsen, 1943; Sutton, 1968; Mehlman, 1989). Fauna associated with Iron Age/Lelesu ceramics on the Serengeti Plains and particularly in the Lake Eyasi basin indicate reliance on wild resources (Mehlman, 1989; Prendergast, 2008). These finds, in rockshelters occupied intermittently over millennia by foragers, raise the possibility that Lelesu ceramics were a trade good for foragers and/or their SPN herding neighbors (Fig. 7). Deloraine Farm, interpreted as emerging from later Elmenteitan communities (Ambrose et al., 1984; Lane, 2013), has evidence of iron-working, livestock herding, and possible finger millet cultivation as suggested by the recovery of a single domesticated grain. The site appears to be unique, despite its location in the most intensively surveyed region of eastern Africa.

Archaeological visibility of iron-using agropastoralists, versus stone-using herders, may help explain the paucity of early Iron Age sites in the Rift Valley (Robertshaw, 1990; Marshall, 2000). It is only in the second millennium CE that iron-working and farming become evident at Pastoral Iron Age (PIA) sites, for example Lanet and Hyrax Hill in the Central Rift Valley (Leakey, 1945; Posnansky, 1967), and on the Mara plains (Siiriäinen et al., 2009). Such Pastoral Iron Age (PIA) sites often leave visible traces in the form of diagnostic ceramics and 'Sirikwa holes', depressions designed as livestock enclosures (Sutton, 1973; Kyule, 1997). Even at this time, the Rift Valley and adjacent highlands such as the Laikipia plateau, remain a mosaic of distinct groups, including foragers living alongside specialized herders and agropastoralists (Ambrose et al., 1984; Causey, 2010; Lane, 2011). Some of these foragers adopted food production only recently, as evidenced at Shulumai Rockshelter (Mutundu, 1999).

4.4. Indian Ocean biological translocations and farming transformations

Our combined archaeobotanical and zooarchaeological datasets document the arrival of non-African species on the eastern African coast from around the 7th century CE, but offer no support as yet for hypotheses suggesting earlier, pre-Iron Age timeframes for these translocations. Our analyses of faunal assemblages from re-excavations at Kuumbi and Ukunju Caves, where controversial reports had been made of third to first millennium BCE chicken and dog (Chami, 2001b, 2004, 2009), could not replicate these findings. Furthermore, our preliminary phytolith studies of both terminal LSA and MIA sediments at Panga ya Saidi (J. Mercader, pers. comm.

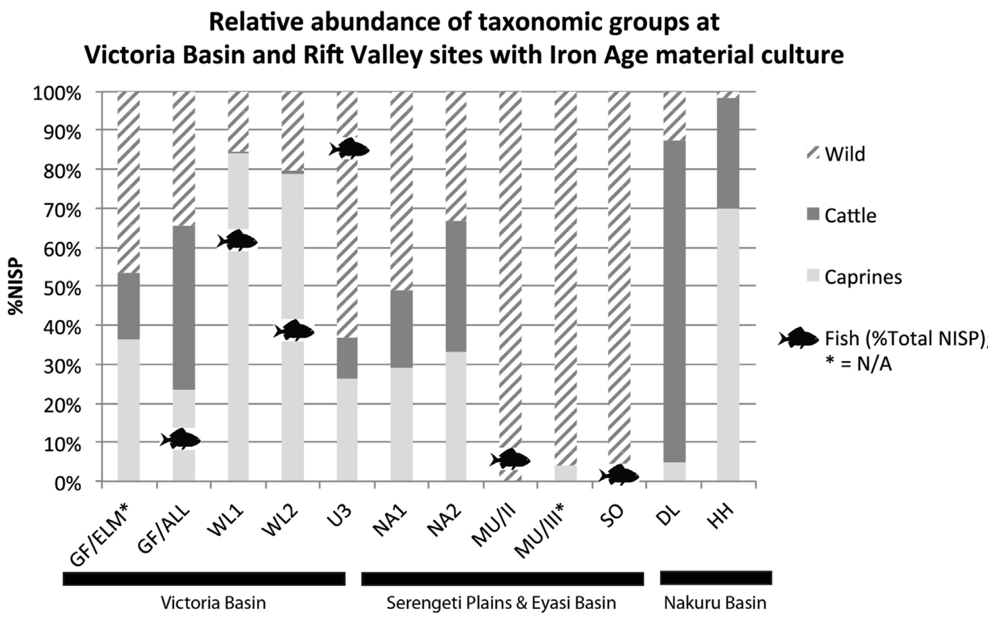

Fig. 7. Frequency of caprines, cattle and wild fauna among terrestrial tetrapod remains (indicated by bar graph), and frequency of fish among all identified faunal remains (indicated by placement of fish icon along y-axis), at sites with Iron Age ceramics. Data did not enable %fish calculation at GF/Elm or MU/III. GF/Elm = Gogo Falls, Elmenteitan levels only, mammalian teeth only (Marshall and Stewart, 1994). GF/ALL = Gogo Falls, all levels combined, fish appear to be under-counted (Karega-Munene, 2002). WL1 = Wadh Lang'o 2001 excavations, Urewe levels (80–120 cm) (Prendergast, 2008). WL2 = Wadh Lang'o 2005 excavations, Urewe levels (Lane et al., 2007). U3 = Usenge 3, Urewe levels (Lane et al., 2007). NA1 = Nasera Rockshelter, Levels 1/2 (PN/IA mixed), teeth only (Mehlman, 1989); NA2 = Nasera, reanalysis of same levels, teeth only (Prendergast, 2008). MUII = Mumba Bed II (Prendergast, 2008). MUIII = Mumba Upper Bed III, teeth only (Mehlman, 1989). SO = Sonai Level I (Prendergast, 2008). DF = Deloraine Farm, MNI rather than NISP data (Ambrose et al., 1984). HH = Hyrax Hill Site II (Kyule, 1997).

2016), as well at the MIA sites of Mgombani (Smith, 2012) and Unguja Ukuu (Le Moyne, 2016), have so far failed to produce any evidence of banana, though these studies are ongoing. The absence of banana from MIA levels at these sites is somewhat surprising, especially at Unguja Ukuu where we have macrobotanical evidence for the arrival of various other Asian crops including rice (*Oryza sativa*), mungbean (*Vigna radiata*), coconut (*Cocos nucifera*), wheat (*Triticum* sp.), and lentil (*Lens culinaris*) within the first century or so of site occupation. These arrivals appear to be linked to a major intensification in Indian Ocean trade as suggested by the concurrent (or perhaps slightly earlier) arrival of imported ceramics, glass beads, metals and other foreign goods of Chinese, Indian and Middle Eastern origin.

The arrival of new food species in eastern Africa does not seem to have radically transformed local farming regimes. Asian crops appeared only in very small quantities (<10% total assemblage) and almost exclusively at trading sites such as Unguja Ukuu (this study) and Tumbe on Pemba (Walshaw, 2015), while African crops continued to dominate for several centuries after these foreign taxa were introduced. The first evidence of a major culinary change occurs only between the 11th–15th century CE, when a shift to rice has been recorded at the site of Chwaka on Pemba (Walshaw, 2015), possibly linked to increasing cosmopolitanism and perhaps also local social competition. The absence of banana phytoliths from MIA levels at Mgombani and Panga ya Saidi in the coastal hinterland might therefore be seen as fitting this broader spatial pattern of limited movement of foreign crops beyond major ports.

Zooarchaeological evidence from our sites presents a similar temporal pattern, with chicken appearing alongside Indian Ocean commensals such as black rat for the first time in the 7th century CE. Similarly, these species appear in very small numbers, comprising <1%–3% of the faunal assemblages at most. However, unlike foreign crops, Asian fauna have been documented at both coastal trading sites (e.g., Unguja Ukuu and previously excavated sites in the Lamu archipelago; see Mudida and Horton, 1996; Wilson and Omar, 1997) as well as smaller, non-trading settlements in the coastal hinterland (e.g., Mgombani; see Helm, 2000), suggesting that they were adopted more readily and widely into local diets, although a cautious approach to identifications might suggest the need for further investigation of such cases.

4.5. Methodological challenges with documenting early farming in eastern Africa

Although our studies have considerably extended existing archaeobotanical and zooarchaeological datasets for early farming in eastern African, these fields are still in the early stages of application in this region, and are thus subject to major constraints, challenges, and biases with respect to the distribution and analysis of data. As discussed above, faunal analyses of EIA sites have been limited by poor faunal preservation, attributable to lateritic burial environments. Additional challenges for Africanist zooarchaeologists studying agricultural transitions include accurately identifying domestic cattle and caprines, whose postcranial bones are often quite similar to those of wild bovids. While excellent reference collections are available in at the National Museums of Kenya in Nairobi, these are not matched elsewhere in eastern Africa, making it difficult for specialists to get the training and resources they need. Misidentification of 'domestic' taxa may be a larger problem than previously thought, as illustrated by a recent debate on the morphological and genetic identifications of early sheep in southern Africa (Horsburgh and Moreno-Mayar, 2015; Scott and Plug, 2016). Identification problems become especially acute when attempting to distinguish osteologically similar imported and local taxa, such as zebu and taurine cattle (Magnavita, 2006) or chicken and guinea fowl (MacDonald, 1992).

The poor preservation of archaeobotanical remains is also an issue (Wetterstrom, 1991b). Seed densities are commonly low, with an average of only 0.83 crop remains (seeds and chaff) found per liter of sediment across all sites listed in Table 3 (excluding the >17,000 rice remains found in only 29 L at Chwaka, which likely represent a burned storage deposit). As a result, relatively large samples need to be floated (e.g., usually 30–100 L per context at Sealinks Project sites), making flotation a very labor-intensive task, especially when using the bucket method as necessitated in Africa by the often remote site locations, the logistical need for mobility during fieldwork, and—particularly in the arid interior—reduced access to water. Low plant remain densities were typical for most of our sites, even the larger, more densely occupied localities with otherwise rich midden deposits such as Unguja Ukuu. Here and at other littoral sites, individual seed remains were often very fragmented and degraded, probably as a result of post-depositional abrasion in the sandy coastal soils encouraged by high water percolation. In contrast, preservation at sites in the coastal hinterland, such as Panga ya Saidi and Mgombani, was comparatively good. Pre-depositional factors could also have some influence on low botanical recovery rates. Young and Thompson (1999) suggest that traditional crop processing methods used for African millets, involving grinding, fermentation, and/or boiling in water, may bias against the incorporation of charred plant remains in the archaeological record, though again, our relatively well preserved assemblages from Kenya do not necessarily support this hypothesis. In addition, most varieties of the African crops are free-threshing, which means that routine de-husking was not necessary, and this may have reduced the loss of grains in domestic contexts (Fuller and Weber, 2005). Another possibility is that the shifting nature of the wattle-and-daub settlements themselves prevented secure stratigraphic build-up of well-preserved deposits. Even today in Kenya and Tanzania, where such architecture is still commonly used in rural villages, households are occupied on a seasonal to generational basis before needing to be moved and rebuilt. Poor preservation may, accordingly, be providing information about patterns of habitation. Another possible explanation, worthy of further investigation, is that EIA sites in the coastal and coastal hinterland region do not reflect classic sedentary farmers, but groups with greater levels of flexibility and mobility across the landscape.

The identification of botanical remains also poses a major limitation to documenting and understanding early farming in eastern Africa, with dedicated reference collections for the region still under-developed and largely focused on cultivated rather than wild taxa. The analyses of parenchyma as well as microbotanical remains such as starch and phytoliths, which are novel techniques that entail specialist training and access to dedicated high-power microscopy facilities, are also in their infancy. Yet without these methods, starch-rich vegecultural crops, which are central to debates about early farming in many parts of the African subcontinent, are archaeologically invisible. In this regard, Africa is seriously lagging behind regions such as Sunda, Sahul and East Asia, where these types of techniques are often routinely employed to address similar debates (e.g., Denham et al., 2003, 2009; Barker et al., 2011; Liu et al., 2013). Compounding these issues is the general lack of research capacity—in terms of both the number of practicing specialists, and the provision of local training and infrastructure—in eastern African archaeobotany and zooarchaeology. With growing recognition of Africa's importance to global models for early farming, however, and the necessity of ancient and modern datasets to address both research questions set out in this paper as well as broader concerns about ancient land use patterns (required for global initiatives like PAGES and LandCover6k), we can look forward to major developments in each of these fields in the future.

5. Conclusion

The eastern African case study presented here adds to a growing database demonstrating the complexity of the prehistoric agricultural transition worldwide, and provides a comparative framework for considering the multi-faceted nature of this process in regions such as East Asia, Sunda, and Sahul. While it is perhaps easy or convenient to conceptualize the spread of farming in sub-Saharan Africa, and other global regions, as occurring rapidly through mass migration (particularly when converging linguistic, genetic, and archaeological evidence seem to offer support for such models), focusing on such monolithic 'events' often obscures our understanding of the more interesting and theoretically informative subtleties of the farming expansion process. As we have outlined in this paper, the transition to farming in eastern Africa was diffuse and asynchronous, and involved a range of intersecting ethnolinguistic groups whose movements and interactions brought about various economic, social, and political transformations over centuries, if not millennia. In this scenario, 'foragers', 'farmers', 'fishers', and 'herders' all played some role in the expansion of farming, whether through directly moving or receiving domesticates through migration, trade and exchange; by participating in the production (and reproduction) of domesticates directly, through client relationships; or through inter-marriage and other socio-economic ties that led to the gradual assimilation of neighboring farming and non-farming groups. Furthermore, the continued dominance of wild resources at many of our early 'farming' sites—in some cases for centuries after the first appearance of domesticates—emphasizes that the commitment to food production was slow and uneven, and not a rapid transition. Accordingly, the boundaries between such well-worn categories as 'forager', 'farmer', and 'pastoralist', which were once easily applied on the basis of assumed correlations between material culture and economic strategies, become increasingly blurred in the light of the higher-resolution archaeobotanical and zooarchaeological datasets reported here (see also Roscoe, 2002 for discussion of these terminological issues). The spatial and temporal variability we see in the appearance of different plants and animals across eastern Africa also serves as a reminder that food production rarely, if ever, spreads as a single coherent package (see also Jones, 2002; Zeder, 2011; Denham, 2013). Instead, the character of farming at any time and place is shaped by the sociocultural choices of the communities that moved and accepted new domesticated species as well as the practices needed to reproduce them, and the technological and environmental opportunities and limitations that enabled or hindered their diffusion. Such a remodeling of ideas about early transitions to farming in many regions of the world challenges long-accepted notions of what 'the Neolithic' actually means, deconstructs monolithic and often dualistic subsistence categories, and challenges simplistic readings of emerging genetic datasets.

Acknowledgements

Our research in eastern Africa has been funded by grants from the European Research Council (206148-SEALINKS) and the National Environmental Research Council Radiocarbon Facility (NF/2011/2/3 and NF/2012/2/4) to NB, British Academy (PF100114) and University of Queensland Postdoctoral Fellowships to AC, Wenner-Gren Hunt Postdoctoral Fellowship (9133) to MP, and a European Research Council Grant to DQF (323842-ComPAg). Permissions to conduct this research were granted by the Office of the President of the Republic of Kenya through affiliation with the National Museums of Kenya; Tanzania Commission for Science and Technology (COSTECH) and Antiquities Division (Ministry of Natural Resources and Tourism, Tanzania); Zanzibar Office of Chief Government Statistician, Zanzibar Research Committee, and the Department of Archives, Museums and Antiquities (DAMA). We gratefully acknowledge the support of the National Museums of Kenya, in particular Dr Ogeto Mwebi, and of the British Institute in Eastern Africa during faunal analyses. We also thank two anonymous reviewers for their insightful comments and suggestions. Finally, we thank those archaeologists in eastern Africa who laid the groundwork for our research, in finding and identifying the many sites that we have revisited, and developing the conceptual models that have inspired our exploration of this topic. Any omissions remain our own.

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