A fast yam to Polynesia: New thinking on the problem of the American sweet potato in Oceania

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This essay revisits Leach's thesis that American sweet potato (Polynesian kūmara*) was first introduced into the Pacific as a variation on* Dioscorea *yam by Polynesian voyagers returning from South America. A review of early agricultural systems on both sides of the first transoceanic* kūmara *transfer clarifies South American disinterest in Polynesian cultigens, but not necessarily why sweet potato was transferred to Oceania as a lone, yam-like root crop. Archaeologists working on Rapa Nui and northern South Island (New Zealand) have identified early* kūmara *cultivation in dry soil planting pits that conform to a widespread Oceanic yam agronomy. Historical ethnobotany sources from Hawai'i reinforce a Polynesian pattern of* kūmara *production in three to six months from planting pits and mounds, compared to nine months or more for yam. Northern South Island evidence also confirms that the planting pit method could provide for* kūmara *cultivation in free-draining soils of low to medium fertility in a climate where yam would not grow. I propose a model in which Polynesians selected South American* kūmara *for transoceanic transfer as a fast growing, hardy survival yam. These versatile* kūmara *qualities may even have encouraged the last great voyages of Oceanic exploration to remote southern Polynesia*.

*Este ensayo revisita la tesis de Leach, la cual sostiene que la batata americana (*kūmara *en las lenguas de Polinesia) fue introducida por primera vez en el Pacifico como una alternativa al ñame* Dioscorea *por navegantes polinesios quienes regresaron desde América del Sur. Una revisión de los sistemas agrícolas existentes en Polinesia y Sudamerica durante la primera transferencia transoceánica de* kūmara *permite confirmar el desinterés de América del Sur en los cultígenos de Polinesia, pero no explica por que la batata fue trasladada a Oceanía como un tubérculo solitario similar al ñame. Arqueólogos trabajando en Rapa Nui y el norte de la Isla del Sur en Nueva Zelandia han identificado cultivación temprana de* kūmara *en pozos de plantación con suelos secos, técnica utilizada en la agronomía general de ñames en Oceanía. Estudios históricos de etnobotánica de Hawai'i refuerzan el patrón polinesio en la producción de* kūmara *la cual se caracteriza por una duración de tres a seis meses para el cultivo en pozos de plantación y montículos, en comparación con los nueve meses o más requeridos para el cultivo de ñame. Evidencia del norte de la Isla del Sur de Nueva Zelandia también confirma que el método de uso de pozos de plantación permitiría la cultivación de* kūmara *en suelos con buen drenaje y de mediana a baja fertilidad en un clima donde el ñame no crecería. En este estudio se propone un modelo en el cual el* kūmara *habría sido seleccionado para la transferencia transoceánica de visitantes polinesios en Sudamérica como un tipo de ñame de crecimiento rápido y que requería de poco mantenimiento para su sobrevivencia. Estas cualidades versátiles de los* kūmara *podrían haber motivado las últimas grandes travesías Oceánicas de exploración hacia el sur de la Polinesia remota.*

Introduction

The first transoceanic journey of American sweet potato (*Ipomoea batatas* (L.) Lam.) and its dispersal to the Polynesian margins as the underground stem crop *kūmara* is one of the most persistent problems of Pacific ethnobotany (Ballard et al. 2005; Yen 1974). Debates over transoceanic sweet potato transfers have included suggestions of avian-borne or sea-rafted *kūmara* origins (e.g., Bahn & Flenley 1992:52-54; Montenegro et al. 2008; Zhang et al. 2004). The last are difficult to model plausibly, however, on both botanical and agronomic grounds (Baker 1971:433-34; Green 2005:43-44; Montenegro et al. 2008; Yen 1974:2-3, 265-266). The proposal that sweet potato was first introduced into Oceania with the advent of post-fifteenth century Iberian voyaging in the Pacific (e.g., McGrail 2001:398; see also summaries in Scaglion 2005 and Yen 1974:3, 5-12) is also countered by botanical *kūmara* identifications to varying levels of assurance from archaeological

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contexts on Rapa Nui, Mangaia (Cook Islands), Hawai'i, and New Zealand that are assumed to pre-date any European introduction (Figure 1 and references or examples in Barber 2004:189-90; Coil & Kirch 2005:74; Green 2005:50-51; Hather & Kirch 1991; Horrocks et al. 2004; Ladefoged et al. 2005; Wallin et al. 2005:86-87; Yen 1974:27; Yen & Head 1993). In fact, there are archaeological indications that sweet potato was a relatively early transoceanic transfer, including a bracketed *ca.* AD 1000-1100 radiocarbon age for archaeological sweet potato tissue from Mangaia (Hather & Kirch 1991), and the inference of temperate *kūmara* cultivation from the time of first New Zealand settlement by about the thirteenth century AD (Barber 2004). Most archaeologists now believe that early Pacific voyagers transported sweet potato into Oceania as remote East Polynesia was colonized during the later first to early second millennium AD (Green 2005; Irwin 2011).

In spite of these strong indications of sweet potato antiquity in Oceania, there are no archaeological or ethnohistoric indications that *kūmara* was ever more than a relatively minor crop in the likely receptor islands of tropical East Polynesia (Green 2005; Yen 1974:260). Furthermore, even in the probable South American coastal source region, sweet potato was but one of a number of edible local root crops (Pearsall 1992). Across the eastern Pacific basin, *kūmara* became economically *and* ritually important only upon reaching the apices of the Polynesian triangle (Green 2005; Kirch 1994). Otherwise, the primary traditional root crops of tropical to subtropical Polynesia were dry soil yam (*Dioscorea* spp.) or damp to wet soil *taro* (*Colocasia esculenta* (L.) Schott) (Kirch 1994).

Herein lies the root problem of the sweet potato in prehistoric Oceania. Why did hypothetical returning Polynesians go to the trouble of transferring a relatively minor American stem crop that would prove to be of little apparent interest to the yam- and *taro*-based island economies of tropical East Polynesia? Alternatively, if American voyagers were the agents of transfer, why introduce a single root crop only among a number of other options? Behind this problem is a more fundamental anthropological question: what does the pre-contact distribution of sweet potato tell us about the process of cultural transfers and diffusion in Oceania, and beyond?

New research offers hope that the core problem is not beyond resolution. Scholars have access to a diverse and growing range of archaeological, other scientific (including DNA) and ethnobotanic data across Polynesia to investigate the sweet potato transfer process, and to ground theoretical models in a more robust database (Ballard et al. 2005; Jones et al. 2011). There is another botanical clue to work with as well. The Polynesian gourd, *Lagenaria siceraria*, is now linked genetically to the Americas. Theoretically, gourd may have rafted naturally into Oceania (Clarke et al. 2006; Erickson et al. 2005; Storey et al. 2011:117, 207-209). However, the shared early distribution of gourd and sweet potato throughout Polynesia *except* for the tropical western islands (Erickson et al. 2005) suggests that the transoceanic transfer of both plants may be linked.

Leach (2005:64) has also contributed an important theoretical perspective in the observation that transoceanic *kūmara* transfers must have required "the plant's acceptance as a new and improved variety of something they [East Polynesians] were already familiar with." For Leach (2005), that familiar reference was the similarly dry Asia-Pacific root crop staple, *Dioscorea* yam. In Leach's interpretation, Oceanic sweet potato became, in effect, a new yam.

This paper continues the conversation about *kūmara* origins in the Pacific. Leach's new yam thesis is evaluated against the following research question.

- What explains the cultural selection, transfer and selective cultivation of sweet potato in Polynesia?

I begin with a review of the evidence for agricultural systems and adaptations on both sides of the first transoceanic *kūmara* transfer to consider why new crops were, or were not, selected. I then test the new yam thesis against archaeological evidence of early dry field production from Rapa Nui and New Zealand, and the rich Hawaiian ethnobotanical record. In this study, I am especially concerned to investigate the early cultivation of *kūmara* in dry soil planting pits that appear to derive from a widespread, cognate, Oceanic yam agronomy.

Pre-Columbian Food Production Systems at the First Meeting of South Americans and Polynesians

The American sweet potato trailhead to Polynesia remains a matter of debate, with coastal Peru (Heyerdahl 1952:428-39) and the Gulf of Guayaquil region (Scaglion 2005; Scaglion & Cordero 2011) both in contention on linguistic and other grounds. The opportunities for sweet potato and gourd transfers from the earliest dated period of East Polynesia colonization are more certain. Archaeological remains of desiccated sweet potato and gourd have been identified along the dry South American coastline south of the Gulf of Guayaquil to central Chile in numerous sites before or by the first millennium AD (Figure 1; Pearsall 1992; Ugent et al. 1981).

Since Heyerdahl (1952:428-39; 1980:233-34), evidence of the vegetative transfer of gourd and sweet potato in particular from America has been the strongest strand of any argument for pre-Columbian, transoceanic contacts. A number of other botanical, faunal and material culture links between Polynesia and the Americas have been proposed, but also contested (Anderson 2006; Arnold 2007; Bahn & Flenley 1992:38-68; Gongora et al. 2008; Heyerdahl 1952, 1980; Jones & Klar 2005, 2006; Jones et al. 2011; Langdon 2009; Lanning 1970; Storey et al. 2008; Van Tilburg 1994:79, 130-31). Even if one allows that these other claims are credible, it is important to note that all of the proposed pre-Columbian plant and animal introductions to the Americas or Polynesia *except for* sweet potato and gourd are highly localized.[1] If confirmed, these other introductions would appear to represent low-impact outcomes from isolated contacts only (Barber 2009).

Transfer by Americans or Polynesians?

Heyerdahl (1952, 1980), Langdon (2001, 2009) and Anderson et al. (2007) have all argued that South American voyagers on bamboo rafts may have introduced sweet potato into Polynesia. Archaeological and historical representations from coastal Ecuador to Peru showing various details of sea-going vessels under sail with directional centerboards raise the theoretical possibility of American voyaging in the Pacific (Heyerdahl 1980:201-28). The feasibility of drift voyaging from South America to East Polynesia, potentially assisted by sail, has been demonstrated experimentally and in simulation (Anderson et al. 2007:126; Heyerdahl 1952; Montenegro et al. 2008). Yet the successful, purposeful settlement of all major islands and island groups of the eastern Pacific is evidence of considerable Polynesian voyaging tenacity and skill as well. In particular, the Polynesian push beyond a west-to-east colonizing trajectory to settle far northern Hawai'i and distant southwestern New Zealand (especially) represent remarkable feats of maritime exploration that may well have involved return voyages of many months duration (Irwin 1992, 2011). To most researchers of the subject, voyaging Polynesians are more likely agents of the first sweet potato transfer than South Americans with no tradition of long-distance Pacific island exploration (Green 2005; Irwin 2011; Kirch 2000:241-43).

Choice and Selection

The vegetative transfer that resulted from this first Polynesian-American meeting, however and wherever it occurred, did not take place in a botanical vacuum. Each party brought specialist agronomic knowledge, preferences and experiences of particular agricultural landscapes to the encounter.

In the course of remote Pacific colonization, the most favorable tropical agricultural environments were the higher volcanic islands where orographic rainfall patterns encouraged distinctive wet windward and dry leeward planting systems over time. On windward island aspects in particular, raised garden beds between channels took advantage of poorly drained or naturally wet lands where reticulate ditch networks facilitated drainage, fresh water flows and nutrient dispersal, especially for *taro* production. *Taro* was otherwise grown in irrigated pondfields, unmodified wetlands, or in deep pits (Addison 2008; Kirch 1994; Spriggs 2002; Spriggs et al. 2012).

In pre-contact island sequences, dry leeward Polynesian environments were dominated by *Dioscorea* yam and aboriculture to varying degrees. Tropical yams require fertile but well-drained soils and about nine months or longer to mature (Handy et al. 1991; Kirch 1994). In the balance of these requirements, Oceanic yams were sometimes planted in pits as well as mounds (*puke*) or even raised beds, depending on soil type and fertility (Leach 2005:65). For example, in Futuna, West Polynesia, traditional *D. alata* setts or seed tubers are planted in mounds (Kirch 1994:82, 116), while tuber setts of *D. nummularia* are inserted into "planting pits" prepared by digging sticks (Kirch 1994:84). On Maupiti (Society Islands), farmers who are "largely 'protected' from mechanized agriculture" plant "competition" yam tubers "in 1-1.5m-diameter holes" of 1-2m depth (Cauchois 2002:272-273). "Consumption" yams are either planted on slopes in small mounds covered with earth and vegetation, or in holes "80-100cm deep and 80cm wide" where between 2 and 5 tubers may be planted (Cauchois 2002:275). The pattern of yam planting in mounds and pits is also recorded in Hawai'i (Handy et al. 1991). Historical records of the latter include details of yams planted on steep slopes in purpose-dug holes 60-90cm deep "filled with earth and decaying leaves" (Handy et al. 1991:180, 182). Another "old Hawaiian method" is also described where a bin constructed of tree-fern trunks was filled with "fern leaves and other rubbish," excluding earth, into which seedling tubers were eventually planted "a few inches below the surface" (Handy et al. 1991:179-180).

On the South American side, extensive raised field systems that drained and redistributed water in lowland areas were constructed after about AD 500-700 in the Gulf of Guayaquil region (Delgado-Espinoza 2002:112-147). To the south, Peru incorporates the world's driest desert spanning the northern to central coast, exceeding the aridity of most Polynesian islands (Figure 1). Complex societies emerged only along the lands of the river valleys that dissect this coastline. Multi-cropped agricultural systems have been developed in this area over millennia, incorporating underground stem plants (including numerous *Solanum* and sweet potato varieties), as well as grass (most notably maize, *Zea mays* L.), cucurbit, bean and tree crops (Pearsall 1992). At the time of the first proposed Polynesian-American contact, coastal Peruvian societies were sustained by substantial irrigation systems at a scale well beyond standard Polynesian wet field systems.

Around the Moche Valley, for example, the largest irrigation works undertaken in South America were constructed under the central administration of Chan Chan, the capital of the imperial Chimu polity, between AD 500-1000 (Billman 2006; Moseley 1983).

Sunken fields that were naturally and in some cases, artificially water-fed supplemented Peruvian irrigation systems (Kautz & Keatinge 1977; Knapp 1982; Matheny & Gurr 1983; Moseley 1969; Moseley & Feldman 1984; Parsons & Psuty 1975). West (1979) documents two groups of "simple water table farming plots" from *ca.* 2000 BP at Viru, suggesting the antiquity of this method. A 1550 Spanish account describes "the valley of Chilca, where … no water is seen to fall from the sky nor does any river or stream pass through it, yet the greater part of the valley is full of plantings of maize and tubers and fruit trees" (Pedro de Cieza de Leon as cited in Rowe 1969:321). Knapp (1982) has also argued that raised embankments at Chilca were designed to trap water for planting surfaces (but see Moseley & Feldman 1984). From the southern Peruvian coast, agricultural field systems including stone-faced terraces, irrigation canal systems and stone alignments are recorded between AD 900-1400, although the association of these features with any particular seed and root crops (let alone particular potato species) is not confirmed (Zaro 2007).

In the hypothetical first meeting of Polynesian and South American agronomists, water-loving *taro* would be unlikely to appeal to Peruvian cultivators at least, while the relatively lengthy Pacific yam growing season would compare unfavorably to potato varieties. Consistently, Asia-Pacific root crops are not recorded in any pre-Columbian American context. The coconut (*Cocos nucifera*) represents the only plausible, if still debated, pre-Columbian plant introduction from the Pacific (Green 2005; Irwin 2011:257-258; Storey et al. 2011:129-132). For Polynesian visitors, in contrast, Peruvian agriculture offered a range of new fruit, seed and tuber crops that could be grown successfully in sunken gardens comparable to yam and *taro* planting pits and wetland or raised bed Oceanic fields and *puke*. This variety highlights the problem that only a single American cucurbit and a solitary tuber were transferred on present evidence, perhaps along with one or two other minor crops (Langdon 1996; Storey et al. 2011). For Green (2005:47), the selection of sweet potato and gourd can be related to root and seed crop familiarity and ease of transfer (as rootstock and seeds). Leach (2005:63, 70) is still puzzled by this limited selection, however, especially when other South American root crops must have been available.

> "East Polynesians already had a good variety of tree crops and a handful of root crops…Why did they bother with a new and unfamiliar one? And why only one of the South American root crops?…While manioc can be considered a most unlikely candidate… most of the others could be grown from seed."

A New Yam for Polynesia

There is no evidence that specialist American agronomic technologies were transferred with the *kūmara* (Barber 2010), consistent with the thesis that sweet potato was selected as a variation on a Pacific cultigen. In particular, it would seem that sweet potato was not cultivated in irrigated fields or reticulated raised beds anywhere in Polynesia (Best 1976; Handy et al. 1991; Kirch 1994; Yen 1974). This is in contrast to archaeological and historical evidence of raised bed or mounded sweet potato cultivation in at least some water-fed South American field systems (Denevan 2001; Yen 1974:65, 148-53). The relationship between *kūmara* and yam agronomy in early Polynesia can be evaluated further from archaeological and ethnobotanical evidence.

Archaeology

Two early dry field trajectories are identified in Rapa Nui and New Zealand at the subtropical eastern and temperate southwestern Polynesian margins respectively (Figure 1). On Rapa Nui, the early dry cultivation of plants in purpose-dug pits and the surface application of stone covers to act as a 'lithic mulch' have been recognized only since the 1990s (Stevenson & Haoa 1998; Stevenson et al. 1999:808; Wozniak 1999). These practices are identified in sequence, and sometimes in combination, at sites investigated across the island (Figure 2). It is proposed that stone surfaces were applied as a later development to regulate temperature, boost fertility and conserve cultivation soils and moisture against desiccating winds and erosion, especially following island-wide deforestation (Bork et al. 2004; Ladefoged et al. 2010; Louwagie et al. 2006; Mieth & Bork 2003, 2004:83-84, 2005; Stevenson et al. 1999, 2006; Wozniak 1999, 2001, 2005).

Stevenson et al. (2006) date a south coast Maunga Orito cultivation sequence from the twelfth century AD where pre-AD 1700 planting pits without mulch are succeeded by stone 'veneer' (grain size 10-20cm) and 'boulder' (30-40cm) gardens. Gardens with a 20-40cm thick stone cover (grain size 5-20cm) above a 25-50cm thick cultivation soil with planting pits are identified in a north-west coast Te Niu sequence that may begin about the thirteenth century AD (Figure 3; Wozniak 1999; 2001; 2005:141). Charcoal is dated AD 1428-1645 (2-sigma calibration) from a "possible" Te Niu planting pit in a lithic mulch garden (Horrocks & Wozniak 2008:130). From the north-east coastal La Perouse locality, an "extensive" (30ha) lithic mulch field system with a "dense" cover (grain size 5-20cm) is associated

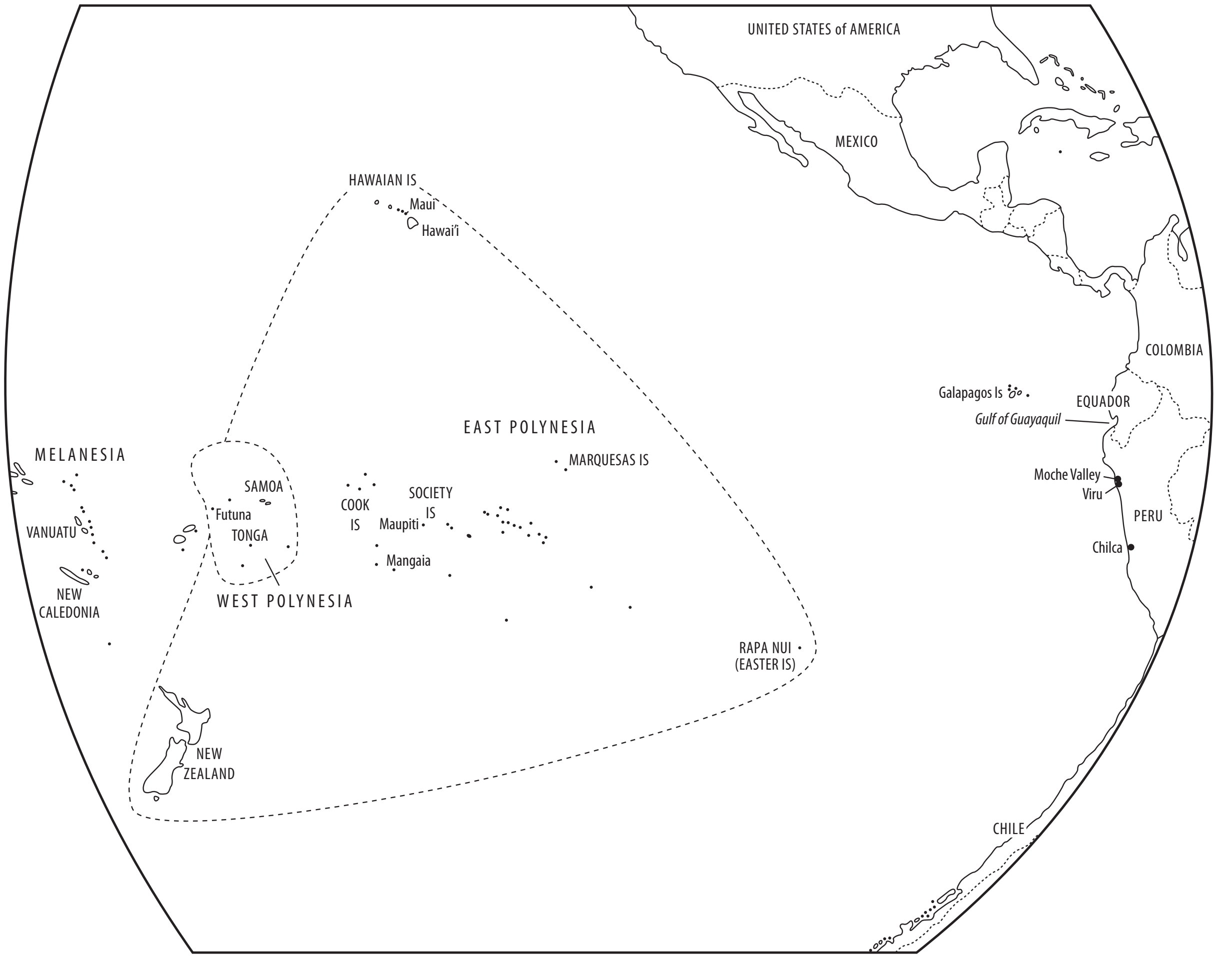

Figure 1. Pacific basin map showing Polynesian (other than New Zealand) and American locations discussed in text.

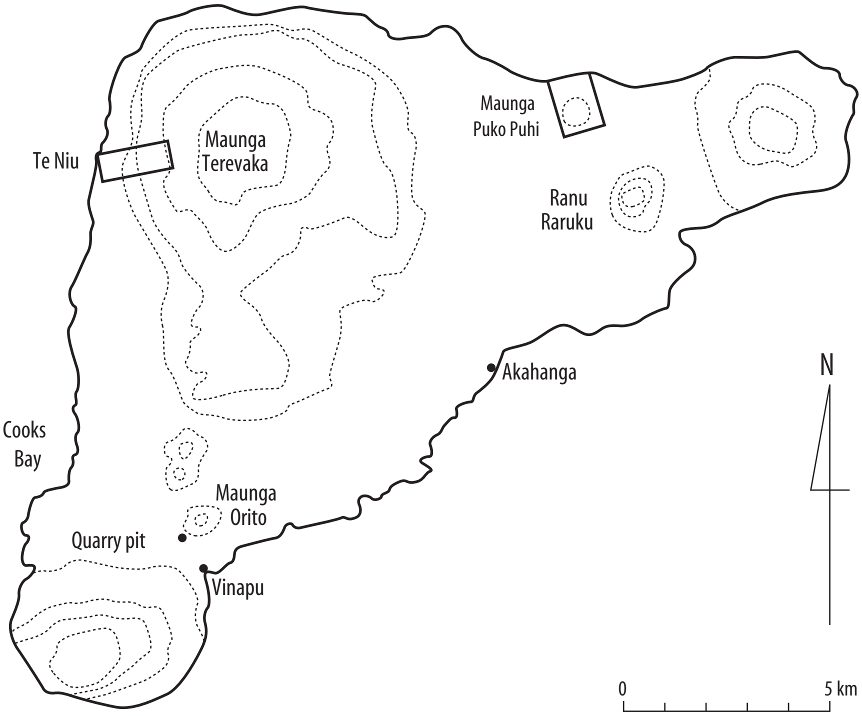

Figure 2. Rapa Nui map showing locations discussed in text.

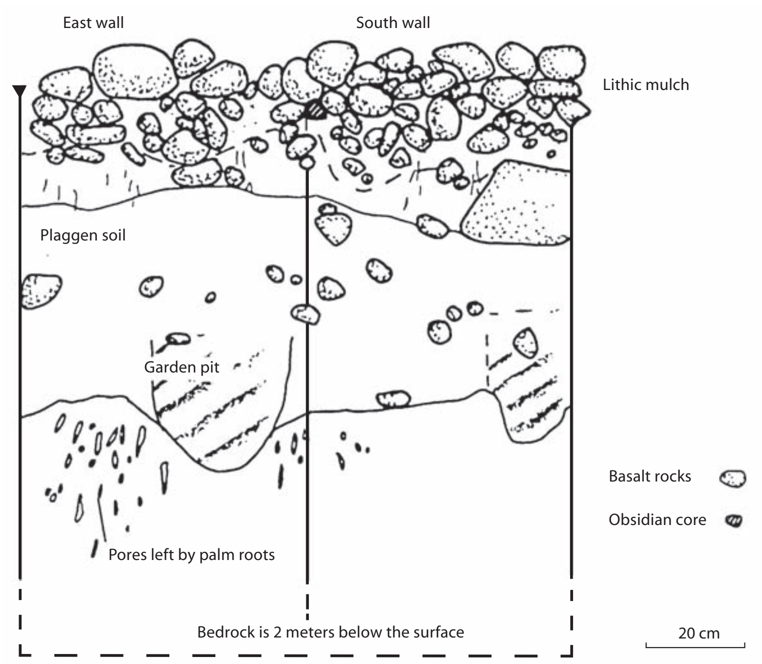

Figure 3. "Typical" lithic mulch soil profile published by Wozniak (1999:Figure 2A) from the Te Niu sampling area, Rapa Nui (see Figure 2). The lithic mulch layer is 30-40cm deep above an agricultural "plaggen" soil that is "dark brown... rich in organic material and... light and porous in texture" (Wozniak 1999:96, Figure 2A). Two planting pits of "darker soil" intrude from the lower plaggen horizon into a clay rich B-Horizon. The B-Horizon is characterized by pores formed by *Jubaea* palm roots from the pre-agricultural forest (Wozniak 1999:97, Figure 2A; see also Stevenson et al. 2006).

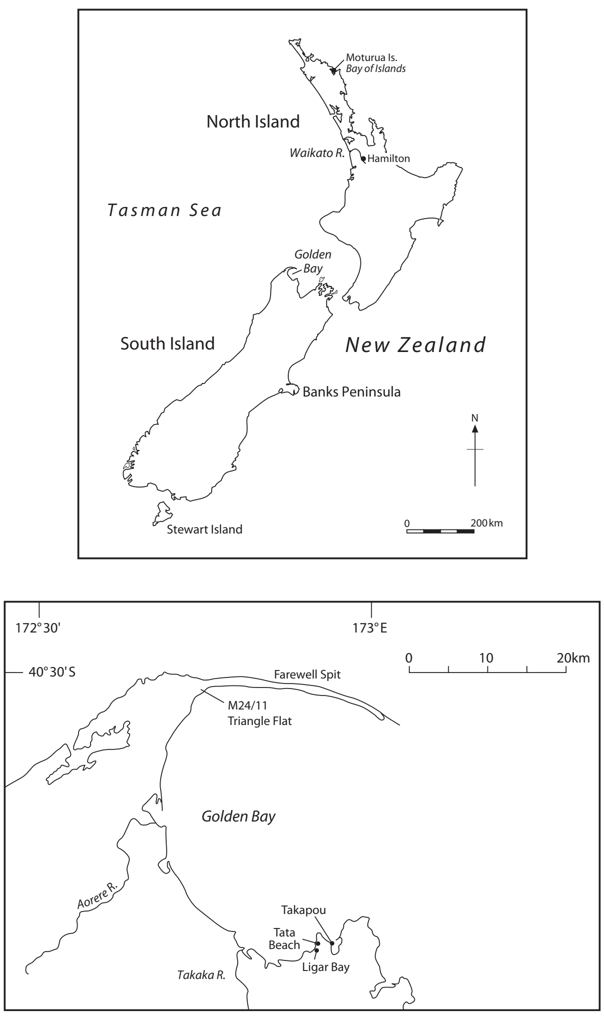

Figure 4. New Zealand and northwestern South Island (Golden Bay) maps showing locations discussed in text.

with occupation between AD 1400-1700 on the flat Maunga Puko Puhi hilltop (Stevenson & Haoa 1998; Stevenson et al. 1999), although the extent of mulch construction there is unclear. Below the hilltop, dated charcoal from a planting pit beneath (and not clearly associated with) a lithic mulch soil is calibrated AD 1149-1398, while a single 'carbon fleck' from a planting pit associated with lithic mulch is dated AD 1460-1632 (2-sigma calibration) (Wozniak and Stevenson 2008:62, 72, 77; cf., pp. 72, 77).

Planting pits filled with fertilizing and, perhaps, moisture-retaining materials would have ensured the availability of a nutritious matrix around the plant. These pits may have been deepened in drier years (Stevenson et al. 2006:934). The identity of cultigens within these features is not directly confirmed. Probable *Ipomoea* microbotanical remains are reported from the anthropogenic Te Niu soils (along with yam and *taro*), although there is as yet no unequivocal botanical identification of sweet potato from early agricultural features (Horrocks & Wozniak 2008). Stevenson et al. (2006:922, 934) propose that sweet potatoes were cultivated in shallow planting pits, while "deeply rooted crops" were grown in deeper pits.

Crop identification is more straightforward in archaeological fields of cooler central New Zealand extending to eastern South Island Banks Peninsula. Here pre-contact Māori cultivation was restricted to gourd and *kūmara* in general. Dry *taro* is reported in one archaeological situation only while yam will not grow in this relatively cool New Zealand region (Barber 2004; Leach 1984).

As discrete site types, planting pits and constructed, rocky cultivation soils that retained heat and assisted drainage are identified from Māori archaeological field systems in northwestern South Island work, although generally not in direct association (Barber 2004:189-190, 2010, *in press* a, *in press* b). Coastal Māori agricultural sites of eastern Golden Bay incorporate shallow planting pits in coarse, infertile granite derived sands (Figure 4). A standard archaeological cultivation sequence for this area includes a very dark grey to black sand upper layer (L1) on a basal layer of brownish-dark grey sand (L2). At Takapou, a sequence of rounded planting pits is identified in an exposed section along a steep eroding dune face (up to 3-4m above high tide). In one place these pits are recorded in sequence as cut from both dark L1 and lighter L2 units, generally <50cm wide and 20cm deep. At Tata Beach, several rounded, non-symmetrical pits between 20-38cm wide are cut from a basal L2 layer into light, culturally sterile sand up to 15cm deep near the crest of a consolidated dune. At Ligar Bay, rounded pits that are generally <40cm wide intrude up to 20cm deep into natural sand at the base of a homogenized L1-L2 unit as recorded in a road cutting across a gentle coastal slope (Figure 5). Calibrated dates on marine shell and short-lived charcoal from L1 to upper L2 middens at Takapou, Tata Beach and Ligar Bay all converge about the sixteenth century AD (Barber 1999, 2003:440, *in press* a). No dates are available on the L2 planting pits cut into sterile sand in any of these locations. These basal pits represent, however, the first human imprint in this area.

Comparable rounded archaeological pits 40-60cm wide and usually about 20cm deep have been investigated at Triangle Flat, northwestern Golden Bay. These pits intrude from the base of a black sand, Māori cultivation A-Horizon into a natural, beach shell and sand ridge (Figures 6 & 7). The pits are sometimes capped by discrete beach shell lenses applied as a hard surface mulch (Figure 7). Starch grains comparable to *Ipomoea* are identified in the microbotanical analysis of fill from a set of aligned, shallow pits, while starch grains

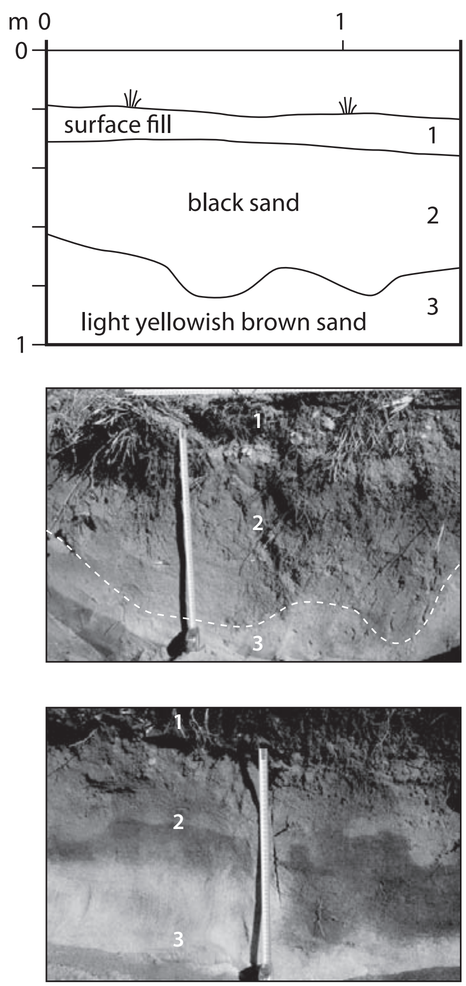

Figure 5. Archaeological planting pits identified by dark sand fill (2) cut into natural, light yellowish brown sand (3), shown in exposed slope section, Ligar Bay, eastern Golden Bay (Photo by Ian Barber, 2006).

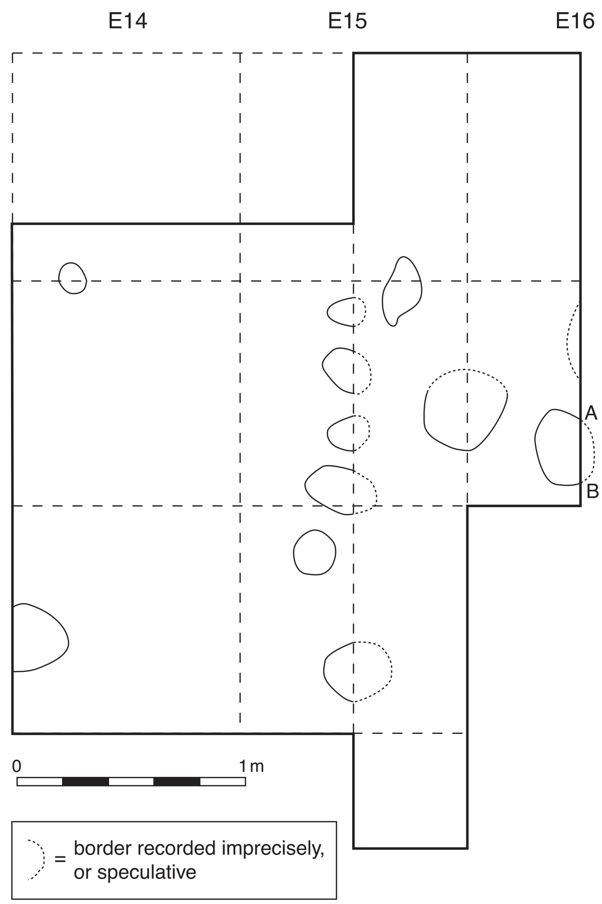

Figure 6. Planting pit cluster in excavation plan, Triangle Flat, northwestern Golden Bay (see Barber *in press* b for further context). Starch grains comparable to *Ipomoea* are identified in black fill from a pit in this cluster (Barber *in press* b; Horrocks et al. 2004:155).

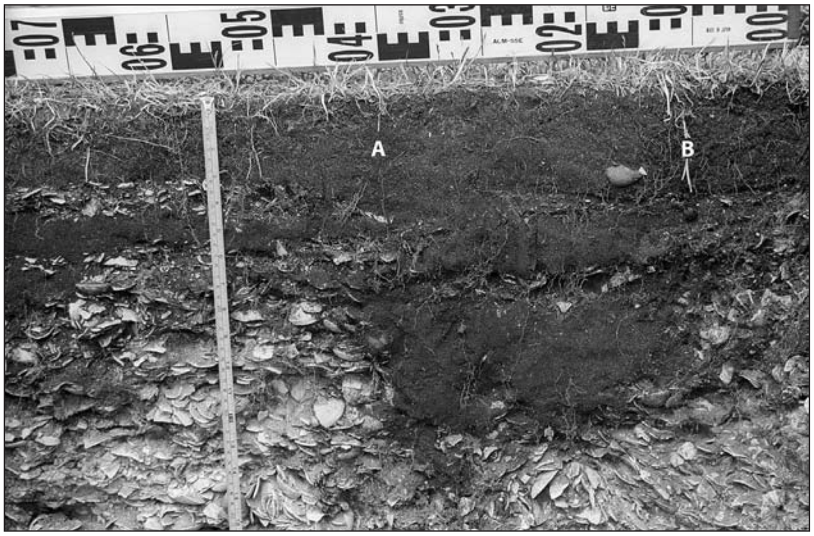

Figure 7. Photograph of planting pit section from Triangle Flat pit cluster (A-B at Figure 6). The topsoil presents a black sand Ap-Horizon incorporating discrete beach shell deposits (interpreted as mulch surfaces in Barber *in press* b). The central planting pit is capped by a beach shell lens and intrudes from the Ap-Horizon into a natural ridge of beach shell and lighter colored sand (Photo by Ian Barber, 2001).

comparable to *taro* are identified in a rare 50cm deep pit (Figure 6; Barber 2004:189-190 and Figure 8.5, *in press* b; Horrocks et al. 2004:149-51, 155). A minimum age for Triangle Flat planting pits is derived from a cluster of calibrated marine dates from midden deposited above, but not in direct association with, several pit features. At two sigma, these Triangle Flat midden dates all overlap about the sixteenth century AD (Barber *in press* b).

These northern South Island planting pits may well represent a cognate, early Polynesian agronomy. Beyond the Rapa Nui evidence discussed above, comparable archaeological dry soil features are recorded on Hawai‘i Island (Allen 2004:198, 216) and from North Island Māori cultivation sites in the Hamilton region of the Waikato River basin (Gumbley et al. 2004) and (with a little less certainty) on Moturua Island, northern Bay of Islands (Peters 1975). It is of particular comparative note that *kūmara* were cultivated in light soils in some early, shallow Rapa Nui pits and in sandy soils in early, and similarly shallow, northern South Island pits.

Ethnobotany

The rich Hawaiian ethnographic record in particular identifies *kūmara* plantings in pits as well as mounds, frequently in combination. From dry slopes on Maui and Hawai‘i in the Hawaiian group, Handy et al. (1991:131) reported *kūmara* cultivation in "small pockets" of disintegrating lava where fertilizer, fine gravel and stones were gathered around the vines "without much mounding". Further to the observation that "ancient Hawaiians planted potatoes in mounds," Handy et al. (1991:130-131) also observed that where the soil was "powdery and dry", the earth was heaped into small mounds only, with sweet potato slips "placed vertically in holes made with the digging stick" so that "the base of the cutting is six to eight inches in the ground" (see also Handy et al. 1991:137 for a traditional account of sweet potato planting holes).

Other Hawaiian observers reinforce the point. Kamakau (1976:24) described excavations for sweet potato slips as "planting holes", while Malo (1951:205) noted that "the soil was raised into hills … or the stems might merely be thrust into the ground anyhow, and the hilling done after the plants were grown." The reports by Handy et al. in particular suggest that sweet potato planting holes were dug in very dry soil conditions (cf. Handy et al. 1991:131 on the practice of sweet potato "high mounding" in damp soils). This evidence is consistent with the convergence of Oceanic yam and *kūmara* planting techniques identified above in the early Polynesian archaeological record.

Ethnobotanical accounts also highlight important growth advantages of sweet potato over dry yam and *taro*. "In particular," Leach (2005:69) has observed, "sweet potato could be planted at any time of the year [in tropical Polynesia], using sections of vine, in contrast with yam which was planted seasonally using tuber sections." For planters in 'Old Hawaii', Handy et al. (1991:127) noted, sweet potato was "more valuable" than *taro* "in three ways":

> "It can be grown in much less favorable localities, both with respect to sun and soil; it matures in three to six months (as against nine to eighteen months for

> taro); and it requires much less labor in planting and care in cultivation."

With respect to the first point, Handy et al. (1991:128) observed that "clay appears to be the only soil to which sweet potatoes cannot adapt themselves." Thus, sweet potato cultivations are reported from humus-rich soils as well as "gravelly semi-decomposed lava" and "in white coral sand mixed with red soil" (Handy et al. 1991:128-129; see also p. 131). On the sweet potato growth advantage, Handy et al. (1991:101, 179) noted that even highly productive wet (irrigated) *taro* crops require six to eight months until maturation, while yam tubers mature after nine months or longer. Malo (1951:42) observed that "the uala [*kūmara*] grows abundantly on the kula lands, or dry plains" and "ripens quickly, say in four or five months after planting." Kamakau (1976:27) also described fast-growing sweet potato varieties "which prevented famine because they bore quickly…as soon as the vines spread out on the mounds they would begin to bear, and in four or five weeks after planting the mounds were full of potatoes."

These ethnobotanical insights begin to clarify the early agricultural record in marginal Polynesia. Planting pits dug into free-draining sandy soils of coastal northern South Island dunes and slopes extended a yam-like agronomy into a relatively infertile growing medium and cool climate that *Dioscorea* – yam would never tolerate. New opportunities and options for dry agriculture may have been important factors also in the planting pit cultivation of *kūmara* in some less fertile Rapa Nui soils and locations (Louwagie et al. 2006). Furthermore, with respect to *kūmara* origins, it seems plausible that hardiness and the relatively short sweet potato growth season were both important considerations for long distance voyagers in the eastern Pacific facing an uncertain landing. Certainly, there is no evidence otherwise that sweet potato storage qualities were necessarily superior to yam for the purposes of ocean transport. Thus, Handy et al. (1991:180) observed that "yams were preferred to sweet potatoes by the captains of Europeans ships because they kept better at sea."

Discussion and Conclusion

With respect to *kūmara*, this essay concludes that transoceanic diffusion can be modeled as part of a cultural process rather than an accident or some inexplicable choice. The first American-Polynesian contact can be explained as the extension of a determined and successful west to east colonization pattern within the tropical Pacific (Irwin 1992, 2011). This context also explains the selection of sweet potato and gourd as cargo for the return voyage to Polynesia from the Americas. Dry gourd fruits could have been used as containers to store water accessed from a departing shore, and then to collect rainwater during the voyage. While pottery vessels might have served the same function, gourd plants were less likely to break and offered organic production opportunities to proficient gardeners (Storey et al. 2011:117). The advantages of sweet potato over other American root crops, including *Solanum* potato, as well as Polynesian yam and *taro*, are twofold: a relatively short growth season, and the capacity to tolerate a range of dry soils and landforms of variable (including low) fertility, such as coastal dunes. This offered the prospect of a root crop harvest within a few months of arrival at any but the coldest of Pacific islands, with cultivation options from shallow pits (notable in some early contexts and less fertile, free-draining environments) through to mounds. In short, sweet potato and gourd were accepted into the inventory of east Pacific voyagers because they lowered the risk of long-distance island exploration in a contribution that may have been as psychological as it was practical.

This process can be modeled further to explain both the low status of sweet potato in East Polynesia, and its prominence at the margins. In East Polynesia, sweet potato was introduced as a survival yam that offered a quick, low-maintenance return to long-distance island voyagers arriving at any of a wide range of island types and climates. However, once the long-distance exploration and interaction phase ceased after about AD 1400 (Irwin 1992, 2011), this advantage was not relevant for the tropical high Polynesian islands and larger atolls with their reliable and potentially more intensive yam and *taro* food production systems (Kirch 1994). With the exception of Mangaia, sweet potato was generally only cultivated at the Polynesian margins on islands with significant areas of dry land (e.g. Rapa Nui, leeward Hawai'I Island, Maui) or a temperate climate (New Zealand) (Green 2005; Kirch 1994).

The fast yam model may even offer a new perspective on the final, and most difficult leg of the Polynesian journey – the exploration and colonization of the southern margins. As noted above, this was an extraordinary feat, as New Zealand lies beyond the predictable winds and currents of equatorial to subtropical Polynesia. Given the likely antiquity of transoceanic contact, it seems that the sweet potato was transferred into a recently settled, East Polynesian home base where populations were experienced in and inclined towards long-distance ocean voyaging. Given the versatile, fast cropping qualities of the sweet potato cultigen, it may have seemed that *kūmara* was "preadapted" to a temperate climate (Kirch 2000:275-76). The possession of this hardy crop may have been an important stimulus to tropical Polynesians leaving on the last great long-distance journey of ocean exploration to the cold south.

Note

1. Heyerdahl (1952:501-504; 1980:230) has proposed that the widely dispersed East Polynesian dog (*kuri*) was a prehistoric American introduction also. However, while the dog is absent from "nuclear parts of Melanesia" such as New Caledonia and Vanuatu in European contact records (Heyerdahl 1952:504; 1980:230), linguistic and archaeological evidence links the dog (proto-Polynesian **kulli*) to western Pacific colonists (Anderson 2003:77-78; Kirch & Green 2001:121, 129; Summerhayes 2007:148). Available haplotype evidence from limited mtDNA sampling also identifies discrete Pacific and pre-Columbian American dog populations with no evidence of contact (Storey et al. 2011:129).

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