Environmental change and human prehistory on Totoya island, Fiji

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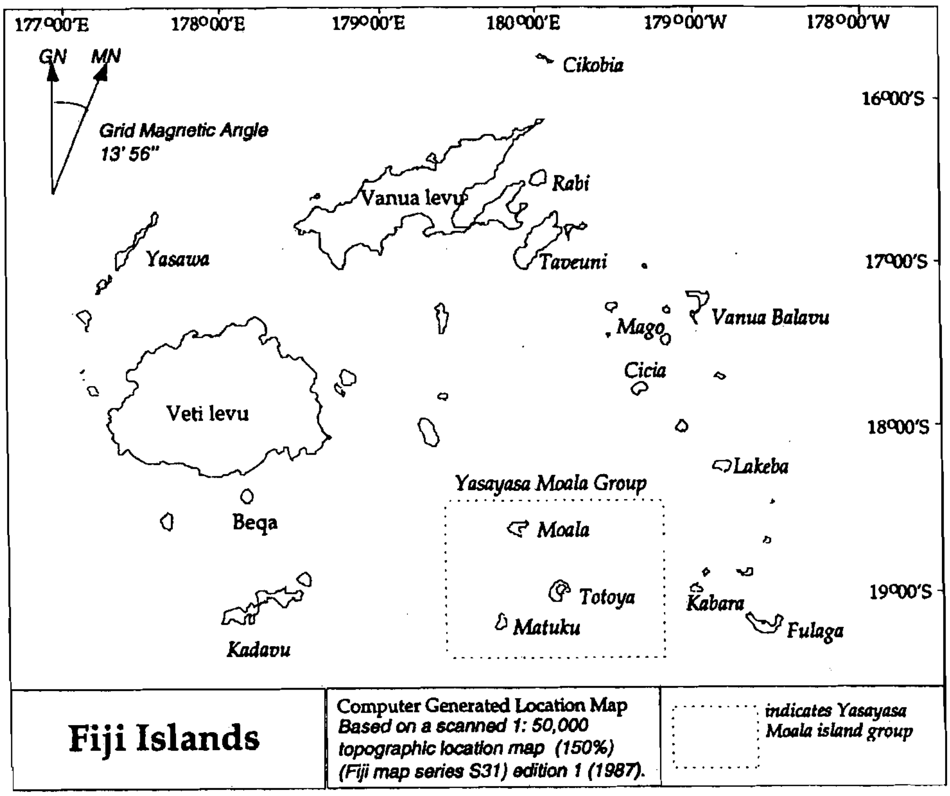
The research discussed here is an interdisciplinary effort to assess the impact of humans on a small-island environment. Certainly, island environments have undergone change over the last few millennia (Nunn 1990, 1991), but what is seldom clear is to what extent those changes are due to human actions as opposed to natural forces, and what effects environmental changes have had on the human settlement systems (Nunn 1992). To address these questions, we conducted studies in archaeology, palynology, geology, geomorphology, and ethnography on the island of Totoya, Fiji. This paper presents a summary of that research project. We conclude that while sea level change affected the island coastline, human actions also played a significant role in the alteration of the Totoya landscape.

Setting

Totoya, along with Moala and Matuku, is part of the small Yasayasa Moala Group, which lies between the large main islands to the west and the small islands of the Lau Group to the east (Figure 1). The islands of the Yasayasa Moala are summits of oceanic central volcanoes (rather than the product of plate-boundary volcanism) on the Indo-Australian Plate close to its northern boundary, and are genetically distinct from adjoining islands within Fiji (Coulson 1976; Nunn 1995a). Totoya is a high basaltic island with associated agglomerates and tuffs. It is a classic example of a breached and flooded volcanic caldera, creating a horseshoe-shaped island open to the south. Coulson (1976) found dikes arranged radially about the center of the caldera. Furthermore, the island is divisible into sections separated by rift valleys or grabens. A sole date for the island is 4.9±0.4 Ma, which was obtained from lavas on the northwest coast (Coulson 1976, corrected by Rodda 1982).

The island and inner lagoon together are 10 km in diameter but the island itself is comparatively narrow, averaging 1.5 km (0.5-3.0 km range) in width (Figure 2). The eroded crater rim has a central ridge spine with numerous peaks (180 to 360 m in elevation) and ridge spurs radiating to the coast. A narrow reef fringes much of the island and an encircling barrier reef creates an outer lagoon with a width of up to 2.5 km. The outer reef is best developed along the windward (south and east) sides and is absent at down-faulted sections in the north and west. The coast of Totoya has many small, scattered flats and valleys with sand and alluvium. Other parts of the coast are cliffed and accessible only at low tide. There are four villages on the island today, all located on the coast: Udu, on the outer shore, and Tovu, Ketei, and Dravuwalu, all on the inner shore. Based on Cole's (1996) vegetation survey, we can identify eight main plant associations:



I Figure 1
A map of the Fiji Islands showing the location of the Yasayasa Moala group. Totoya Island is located between the neighboring islands of Moala and Matuku (after Fiji Map Series S31/32 1986).

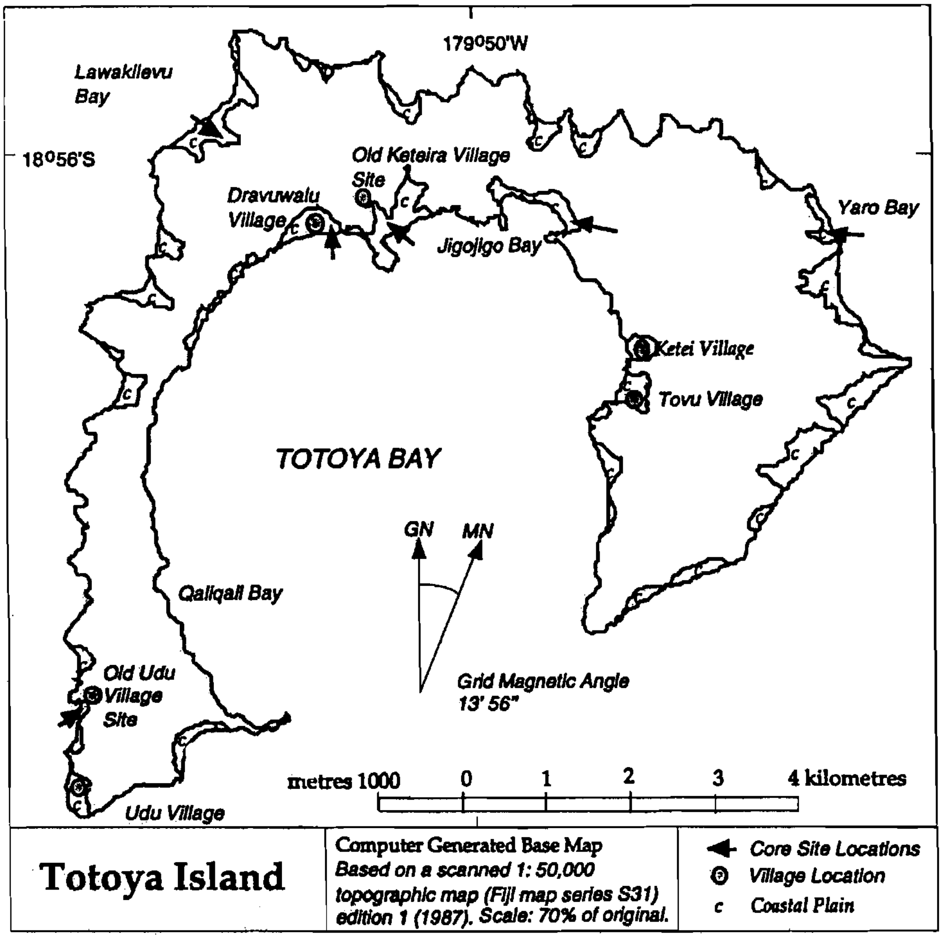


Figure 2

Base map of Totoya Island. Fringing and barrier reefs are not indicated. Approximate locations of the six pollen core sites are indicated by small arrows (from Fiji Map Series 1987).

1) Mangrove Forest, 2) Coastal Zone Vegetation, 3) Cibicibi (Maniltoa brevipes) Forest, 4) Cau (Casuarina nodiflora) Forest, 5) Talasiga (Fijian grassland association, primarily Miscanthus floridulus), 6) Coconut Plantation, 7) Pine Plantation, and 8) Village Gardens.

Geology

Nunn's geological investigation involved a study of shoreline indicators of past sea level, a search for evidence of tectonic movements, and an assessment of the processes affecting the development of the coastal lowlands. His investigation confirmed the presence of evidence indicating a former relative sea stand higher than present and of coastal progradation in the lowlands.

The indicators of emergence on Totoya range from cave-fringed rock platforms to emerged beachrock and beach sediments. Most of the original data were collected and analyzed by Rook (Rook, Farnell, and Lewis 1986) who concluded that there was good evidence for emergence of about 1.5 m. This emergence is probably the consequence of a late Holocene high stand of sea level and subsequent fall.

As a result of Nunn's investigation, three of the raised beaches on Totoya have been dated to the Holocene sea-level maximum, all in the southwest part of the island near Udu village. From Valelevu on the outer coast, beachrock at 1.45 m above mean sea level was dated to 2470±50 BP, and underlying beachrock at 0.47 m above mean sea level was dated to 2620+/-50 BP. These dates are interesting as they appear to signal a minor transgression within the main late Holocene sea-level fall that took place after ca. 3000 BP. Beachrock exposed in the side of a small pool about 300 m north of Udu was dated to 1930±50 BP. These beachrocks may mark minor oscillations within the course of Holocene sea-level change, or they may simply represent periods of stability of the ocean-land interface (Nunn 1995b). And finally, there is evidence of a sea-level rise in the last few decades, which is probably part of a regional pattern.

In the 1920s, Davis (1920, 1928) produced a model for the post-volcanic development of Totoya in which subsidence was the major process. While this model is largely correct in identifying the succession of stages through which Totoya passed, the weaknesses of Davis' argument are that he equated submergence with subsidence rather than with subsidence plus sea-level rise, and he probably overestimated the amount of subsidence that occurred. Refining the model, Nunn (1995a) proposes a four stage posteruptive history of the island. The first stage involved an asymmetrical caldera forming as the result of both explosion and subsidence. The second stage involved denudation and accumulation of eroded sediments in valley bottoms and along coasts on a subsiding landmass. These processes varied in importance throughout the Quaternary as climate and sea level changed. The third stage is associated with Holocene submergence, mostly the result of sea-level rise rather than subsidence, which created many coastline embayments. Fourth, a late Holocene sea-level fall contributed to the development of the coastal plains now filling most of these embayments (Figure 3a and 3b). Many of these plains are now being eroded slowly as the result of sea-level rise over the past few decades.

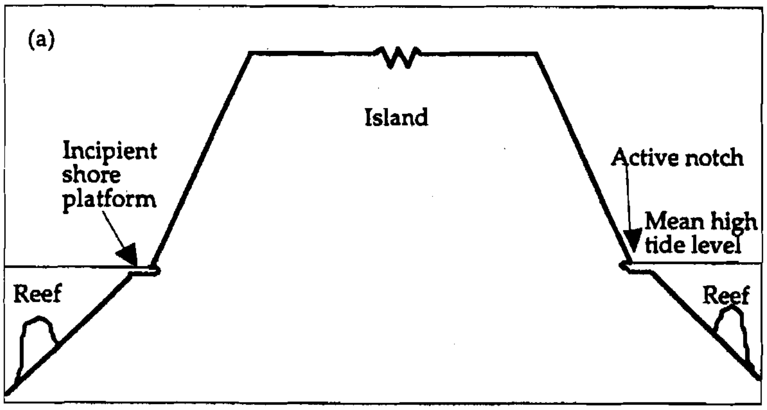


Figure 3a.
Geomorphological conditions likely to have existed on Totoya and other oceanic islands at the time of the Holocene sea-level maximum ca. 5000 BP (after Nunn 1994).

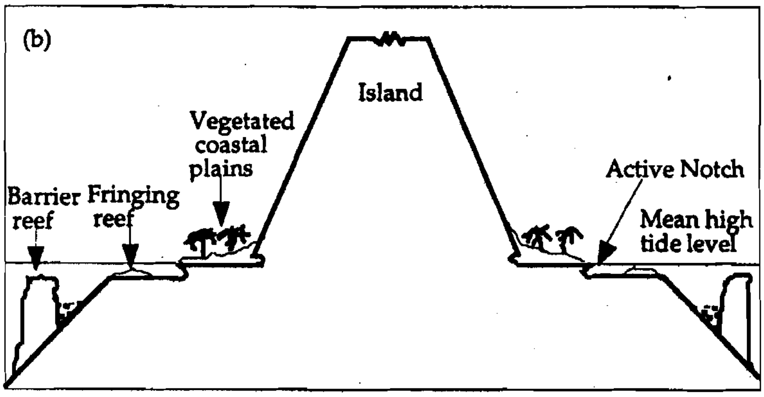


Figure 3b
Geomorphological conditions likely to have existed on Totoya and other oceanic islands as a result of the late Holocene sea-level regression (after Nunn 1994).

Palynology

The palynological fieldwork conducted by Cole (1996) consisted of the identification of suitable core sites, core removal, vegetation surveys of core sites as well as general coastal and inland vegetation zones combined with the collection of voucher specimens. Six cores were extracted (Figure 2) using a standard D section and Hiller Corer. The cores were sealed in PVC plastic casing and shipped to Massey University where initial x-ray photography was used in the analysis of core stratigraphy prior to sampling and preparation. The pollen samples were handled in accord with the absolute pollen technique, as described by Stockmarr (1971) and Bonny (1972). Several radiocarbon determinations were obtained from the cores (see Cole 1996).

The palynological, stratigraphic, ecological modelling, and observational evidence indicates that large-scale modification of the Totoya landscape and vegetation has occurred since human settlement. There has been significant destruction of the island's inland forest vegetation, primarily by forest fire. While human land clearance practices are likely to have been the primary cause of the fires, we must stress that the human impact hypothesis cannot be tested on the basis of palynological data alone. The ecological modelling carried out by Cole (1996) indicates that it is possible to misuse palynological data to defend the human-impact paradigm in the absence of rigorous hypothetico-deductive scientific methodology (Mentis 1988). Until research of this kind is forthcoming, one can only conjecture as to the real causal mechanisms responsible for vegetation change on small oceanic islands such as Totoya. It is the absence of non-trivial alternative hypotheses, and field data to support them, that has traditionally resulted in support for the human-impact paradigm. Taken in this context, the palynological data from Totoya clearly implicates human impact as a primary mechanism of vegetation and landscape change on Totoya

Coinciding with a history of forest fires (microscopic charcoal fragments), enormous amounts of terrestrial sediments (especially clays) were deposited on the coastal plains of Totoya over the last two thousands years. Ecological models based on proxy data for inland forest soil erosion indicate that the distinctly non-equilibrium organization and behavior of the island's mangrove forests is linked to inland forest disturbance. Furthermore, ecological modelling played a crucial part in discriminating between human and non-human causes, suggesting that hypothesis-testing analytical techniques of this kind should be a routine part of palynological investigations related to human impact studies.

A fascinating discovery from the modelling of the Totoya mangal is that these ecological communities have a form of disturbance memory. Present community organization, for example, is being shaped by disturbance events that occurred over a century ago. As a result of this modelling, the classical mangrove succession paradigm of Davis (1940) was rejected in favor of the opportunistic, non-equilibrium paradigm of Thom (1967, 1979).

At all six core sites there has been a general increase in coastal zone vegetation in recent times associated with the disappearance of the inland forest. This plant association is composed of only a few species historically represented in inland coastal or marginal vegetation. This coastal zone association appeared in the late Holocene in response to two factors. First, the development of Totoya's coastal plains in response to falling sea level, aided by the deposition of terrestrial sediments released as a result of the loss of inland forest cover. Second, the introduction of exotic plant species by human settlers. There was also an increase of Palmae pollen, as much of the coastal plain today is covered by coconut palms.

Also at all six core sites there is a progressive increase in grassland vegetation. At the well-dated sites (Yaro, Lawakilevu, Keteira, Udu) the rise of grassland vegetation covers the times of both the Little Climatic Optimum (1200-650 BP) and the Little Ice Age (650-50 BP) (Nunn 1992). Neither of these climate changes appears to correlate with the arrival of grassland vegetation on Totoya in a causal manner. Because the fossil pollen record does not predate the arrival of humans on the island it is not possible to test for the existence of a pre-settlement period of aridity.

Archaeology

The archaeological fieldwork directed by Clark was primarily pedestrian survey. A significant portion of the island was examined, although variations in terrain and vegetation affected island coverage. Nearly the entire coast was checked, an exception being a small stretch on the western inner coast where there are no valleys or coastal flats suitable for occupation. Other areas not examined were some of the inland peaks and ridge tops, most of the ridge slopes, and areas covered with dense talasiga.

For survey data such as those collected on Totoya to be of most use, the artifacts collected from the various sites must be fit into a chronological sequence. Gifford's (1951) pioneering work in Fiji led him to define two ceramic traditions, Navatu and Vuda, for Viti Levu. Green (1963) later added an initial Sigatoka Phase and a terminal Ra Phase. Subsequently, Shaw (1967) and Frost (1979) presented slight modifications, and Hunt (1980; 1986) proposed a new phase, which he termed Yanuca, between Sigatoka and Navatu. The most detailed ceramic study was made by Best (1984) based on data from Lakeba, in the Lau Group. Best abandoned the named sequences and adopted a series of four Periods. Working on Beqa, Crosby (1988) also used series of numbered periods that could broadly be correlated with the periods and subperiods of Best.

A review of the various excavation reports and sherd descriptions for Fiji indicates that a single sequence with uniform dates cannot be established. Given the varying degrees of isolation and the differing contacts with islands within and beyond Fiji, variations in sequences are to be expected. Thus, detailed ceramic sequences must be worked out locally. Nevertheless, there are some important, common threads that run through the

Period I. >1000 to 1 BC
  1. Sigatoka Phase. Lapita occupation, >1000 to 500 BC
    1A. Early Sigatoka: Dentate stamping, >1000 to 750 BC
    1B. Late Sigatoka: Mostly plain, some rim decoration: 750 to 500 BC
  2. Yanuca Phase. Transitional: slips and burnishing, possibly some paddle impression: 500 to 1 BC

Period II. AD 1 to 1000
    3. Early Navatu. Paddle Impressed, AD 1 to 500
    4. Late Navatu. Paddle Impressed, AD 500 to 1000

Period m. AD 1000 to present
    5. Early Vuda. Incised and Applique, AD 1000 to 1500
    6. Late Vuda. Complex Incised and Applique, AD 1500 to 1770
    7. Ra. Historic, Post AD 1770

Table 1
A generalized of a Fijian ceramic sequence.

archipelago. For present purposes, therefore, we will employ a new model of a generalized Fijian sequence based primarily on periods, subperiods, and infraperiods of 1000, 500, and 250 year blocks, respectively. The full range of variables characterizing each of these time units which have been gleaned from various studies in Fiji cannot be specified here, but some crucial variables are outlined in Table 1.

At least eighty-four sites were found around the island. The distribution of these sites, in very general terms, is as follows: 29 sites in the coastal lowlands around the outer shore, 26 sites along the inner shore, and 29 sites in the uplands (slopes, ridges, and peaks). These sites include large and small residential settlements, hilltop forts, ring ditch forts, a rock shelter, fishpond/traps, adze sharpening areas, a large mound, a Tongan tomb, a beach rock quarry, canoe/boat landings, and historic features. A preliminary chronological distribution of these sites in given in Table 2, but we stress that this is only a working formulation that will undoubtedly require modification when and if sites are tested.

Undecorated body sherds make up most of the artifact collection, though a large quantity of decorated sherds was also found. The vast majority of decorated sherds have paddle impressions. Comparatively few show incising, applique, and other decorative techniques, and only four have Lapita dentate-stamping. A small sample of sherds was sent to William Dickinson foographic thin sectioning and analysis. A second set of sherds were analyzed by Stepr petrhen Adamek, Miriam Grenz, and Dean Grier North Dakota State University using X-ray diffraction.

Stone artifacts were not common at these sites, but a small collection was made of flakes and tools. Most of these artifacts are pieces of silicious stone (chert and jasper) that Peter Rodda, geologist for the Ministry of Lands and Mineral Resources, Fiji, identified as almost certainly not local to Totoya (Rodda, pers. comm., 1993). Of the 34 silicious artifacts, almost half are flake tools, the remainders are flakes, shatter, cores, and hammerstone fragments. Six adzes were recovered from the surface, at least two of which are not local to Totoya. An additional three artifacts are of basalt: one core, one flake tool, and one waste flake.

Excavations were limited to three, one-meter-square, test pits at the Lawakilevu site, locality 7, where two decorated Lapita sherds were recovered from the surface. This locality is approximately 80 m inland of the present shoreline, and 10+ m from the ridge that borders this small valley section. The ground near this spot is quite low and often muddy from the ephemeral surface flows that ribbon over this section of the plain.

AREA	PERIOD	SITES
OUTER SHORE	I. 1	Udu, Lawakilevu, Waroka
	I.2	Udu, Lawakilevu, Waroka, Valelevu, Laselase-Bouwaqa, Naivaka, Navu, Navuli, Namara
	II.3	Udu, Lawakilevu, Waroka, Valelevu, Navu, Namara
	II.4	Udu, Lawakilevu, Waroka, Valelevu, Doi, Naivaka, Navu, Yaro, Navuli, Namara
	III.5	Udu, Lawakilevu, Waroka, Valelevu, Laselase-Bouwaqa, Naivaka, Navu, Yaro, Namara, Matasawa
	III.6/7	Udu, Valelevu, Doi, Laselase-Bouwaqa, Naivaka, Yaro, Navuli, Bulila, Matasawa
INNER SHORE	I. 1:	none
	I.2:	Tovu, Jigojigo, Keteira, Dravuwalu, Yawalevu
	II.3:	Keteira, Dravuwalu
	II.4:	Lovoni, Taburai, Tovu, Jigojigo, Keteira, Dravuwalu
	III.5:	Jigojigo, Yawalevu
	III.6/7:	Tovu, Ketei, Korovusa, Jigojigo, Keteira, Dravuwalu, Yawalevu
INLAND	I.1:	none
	I.2:	none
	II.3:	none
	II.4:	Tota, Rukui Talau
	III.5:	Tota, Rukui Talau, Delaisalia, Veisika, Lekubi, Koronabuni, Bueri
	III.6/7:	Nakororewa, Davura, Dakunikoro, Korosigani, Delaisalia, Veisika, Lekubi, Koronabuni, Bueri

Table 2
Preliminary chronological distribution of sites. Periods m.6 and m.7 lack sufficient ceramic distinction to differentiate on the basis of surface collections.

Two layers were encounter in excavation: Layer I, an overlying cultural layer, ca. 20 cm thick, of dark sandy loam with abundant shell, coral, and stones; and Layer II, beach sand with coral rubble of an old beach ridge. Although no additional dentate-stamped sherds were recovered, several very thin, slipped and burnished sherds were found in a thin band overlying and into the old beach ridge. These sherds could fit into either a

Period I.1 (Lapita) or Period I.2 assemblage. Two tridacna shells from the interface of layers I and II yielded adjusted radiocarbon ages of 2480±60 and 2370±60 radiocarbon years. Calibrated at 2-sigma, but without a delta-R correction (not established for Fiji), these dates are 2295 (2114) 1958 BP and 2125 (1972) 1836 BP, respectively (CALIB 3.0.3; Stuiver and Braziunas 1993). The shell dates could be off, but a more likely alternative is that a Period I.1A, Lapita, occupation existed nearby, probably more inland.

To summarize the archaeological findings, initial settlement of Totoya was along the outer shore at locations such as Lawakilevu, Udu, and Waroka. This took place during the Lapita occupation of Period I.1A. By Period I.2, sites were spreading along the outer shore and eventually along the inner shore. The distribution of paddle-impressed sherds indicates the spread of occupation into the interior during Period II. Sherds from Period III, especially III.6, are also found at inland locations, particularly at hill top forts, and at lowland sites, especially where there are ring-ditch forts. Preliminary materials' analyses indicate that valued stone resources were coming to Totoya prehistorically from other islands in Fiji and from as far away as Samoa. This is indicated for periods I.1 and III, possibly II, but not, as yet, for I.2.

Ethnography

The ethnographic component was under the direction of Dr. Eric Waddell, although he was not able to participate directly in the research. Eight students from University of the South Pacific in Suva conducted interviews with residents of the four villages on Totoya. Those interviews were designed to gather information on cultivation practices, changes in vegetation and landscape, recent island history, socio-political organization, island economics, and oral traditions. The interviews also elicited information about site locations, especially on the inland ridges and peaks. The ethnographic interviews produced a wealth of information that will enhance our picture of the human-environment interactions on Totoya but is not directly pertinent to the present discussion.

Summary

Based on the combined archaeological, palynological, and geological data, we propose the following model of island environment and settlement system change. This formulation is a working model that attempts to incorporate the available data in a coherent fashion. From this model, testable hypotheses can potentially be framed for future research.

The human colonization of Totoya occurred when the landscape was vastly different. Sea level was higher, the coastal plains had not yet developed, the mangrove zones were absent or small, and Cibicibi forest covered much of the island. Over time, the environment changed substantially due to human actions and natural processes of change.

The archaeological data suggest that the earliest settlement was along the outer shore. Such sites would allow for easy access to the open ocean as well as to productive lagoon resources. Lawakilevu, north Udu, and Waroka were settled very early. The presence of dentate Lapita sherds at all three locations indicates settlement prior to 2500 years ago--perhaps a few centuries prior, or Period I.1A. The radiocarbon dates and pottery from excavations at Lawakilevu also suggest occupation in the first couple of centuries BC, or Period I.2. If Nunn is correct about the higher sea stands, the period I.2 occupation would have been along an ancient shoreline, and the Period I.1 occupation would have been somewhat more seaward since the sea level was even higher some 3000-2500 BP.

The sedimentary and palynological data suggest that human settlement of Totoya was underway some 200-400 years before the development of the coastal plain, which also lagged behind the sea level fall from the late Holocene high. While falling sea-level drove the process of coastal progradation on Totoya and other oceanic islands (Nunn 1990), the late initiation of coastal plain construction suggests that other factors were also involved.

The mangrove forest found on the island today is very likely to have been introduced about the time of human colonization. Only two of the seven mangrove species known for Fiji (Excoecaria agallocha and Bruguiera gymnorhiza) are found on Totoya, which is close to the southern and eastern limits of mangrove distribution (Saenger and Moverly 1985; Woodroffe 1987; Woodroffe and Grindrod 1991; Latham 1979). It seems likely that the necessary substrate and sediment supply for mangal development were not available on Totoya until after the late Holocene sea-level maximum, when the island's barrier reef re-emerged and offered protection from the high energy window of the sea-level maximum (see Figure 3) (Nunn 1994).

With settlement at a given site, humans initiated forest clearance that progressed to a peak over a couple of centuries. At each site cored there are two distinct, successive peaks Yaro is an exception with three expansions. These periods are indicated by marked charcoal concentrations in the pollen cores that reflect burning of the inland Cibicibi forest. This activity resulted in an initial influx of surface sediments onto the coastal plain, which allowed mangrove forest to establish and expand. Apart from the two charcoal concentrations noted, there is also a relatively high background level of charcoal. This probably indicates continuous use of fire as an agricultural tool.

Secondary inland vegetation (eg., grassland and possibly secondary forest) followed the clearance, but also slowed the rate of erosion and sedimentation in the coastal lowlands. Some centuries later there was a second wave of inland forest clearance with subsequent increased erosion and sedimentation on the coastal plain. That, in conjunction with the lowered sea level from the late Holocene high, pushed a seaward shift in the intertidal zone that formerly had supported the pioneer mangrove forest. Hence, the mangrove forest migrated farther out onto the developing coastal plain.

All of the core sites that show fossil pollen evidence of decline in the Cibicibi forest only show the very last stages of the forest disappearance, the deepest core dating to ca. 1621-2100 BP (calibrated 2-sigma). There are two sensible explanations for this. First, the fires that destroyed the island's Cibicibi forest may have begun centuries before, possibly with initial human settlement. If the inland forest vegetation of Totoya was destroyed by human-induced fires, this suggests human settlement much earlier than the date from Lawakilevu excavations and supports the contention based on ceramic typology of settlement at least 2500 years ago. Alternatively, the Cibicibi forest may have already been partly or largely damaged due to climatic conditions by the time the first settlers arrived on the island. The second hypothesis seems unlikely in light of the increase of Poaceae fossil pollen evident at all six core sites. If the forest was already damaged at the time of human settlement, then presumably the grassland vegetation would have been better established.

Pollen data, when viewed in the light of the lag time between human activity and the reflected vegetation and geomorphological change, suggest that between about 2500 and 2100 years ago, settlement had reached Yaro Bay on the outer shore and Dravuwalu on the inner coast. The pollen data further suggest occupation of Keteira (inner shore) slightly later than at Dravuwalu, but still within the same general period. Presumably this was so at other locations, too. Ceramic evidence in the form of probable Period I.2 vessels at Yaro, Valelevu, Dravuwalu, and possibly Tovu support this contention. The onset of substantial burning and sedimentation by the end of this Period I.2 is consistent with the findings from Lakeba (Best 1984:643). If human colonization was substantially prior to 2500 BP as suggested by the dentate Lapita sherds, this may lend support for Best's (1984:652) suggestion that the first few centuries of occupation in Fiji may have been by non-agricultural, marine-oriented populations.

A second round of substantial vegetation disturbance first occurred in some areas around 1700 BP. This second phase probably relates to a significant move inland and the establishment of inland villages or dispersed settlement. That date follows the suggested beginning of Period II and would also be concordant with the postulate lag of a century or more in vegetation response to disturbance. Paddle-impressed sherds of this period were found at sites inland as well as many areas along the inner and outer coastlines. This would reflect continued population increase, which is consistent Crosby's interpretations of Beqa, though not with Best on Lakeba. However, the fact that forest disturbances came considerably later at some locations (i.e., Jigojigo Bay about 1200 BP and Lawakilevu by 1000 years BP) suggests that population growth was slow. The presence of quartz in some sherds from this period suggest interisland contacts.

The final decline of the inland forest correlates with the last part of the prehistoric cultural sequence, which was Period III.5 when hilltop forts were established at several locations around the island. Ring ditch forts found in the valleys and at low elevations probably represent Period III.7, historic occupation, and perhaps even late Period III.6. These sites reflect the return to an emphasis on coastal settlement. It was in Period III.6 that Tonga influence first began, and it carried into Period III.7. The fishpond/traps were probably established during Period III.7, as some of them were still in use into this century. One can only speculate as to whether the sea level rise documented for the last several centuries played a role in the abandonment of most these features. Ceramics of Period III appear to exotic, though some were still locally manufactured, at least in the earlier in the period.

Acknowledgements

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