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The Ideal Free Distribution, Food Production, and the Colonization of Oceania

Douglas Kennett, Atholl Anderson, and Bruce Winterhalder

Islands in Oceania were some of the last habitable land masses on earth to be colonized by humans. Current archaeological evidence suggests that these islands were colonized episodically rather than continuously, and that bursts of migration were followed by longer periods of sedentism and population growth. The decision to colonize isolated, unoccupied islands and archipelagos was complex and dependent on a variety of social, technological and environmental variables. In this chapter we develop an integrative, multivariate approach to island colonization in Oceania based on a model from behavioral ecology known as the Ideal Free Distribution. This ecological model provides a framework that considers the dynamic character of island suitability along with density-dependent and density-independent variables influencing migratory behavior. Unique among existing models, it can account for the episodic nature of certain aspects of the colonization process. Within this context we critically evaluate the role of foraging, low-level food production, and ultimately intensive food production, as important contextual variables that influenced decisions to disperse. We argue that intensive food production was one variable that contributed to decreasing suitability of island

habitats, stimulating dispersal, and ultimately migrations to more distant islands in Oceania.

The processes involved in the development of food production worldwide during the last 10,000 years were complex and spatially variable. At a minimum, they involved some combination of the following set of factors: (1) the expansion of diet-breadth during the late Pleistocene and early Holocene, leading to the development of co-evolutionary relationships between humans and potential domesticates (Richards et al. 2001; Rindos 1984; Stiner et al. 1999, 2000; Winterhalder and Goland 1997); (2) intensified exploitation of wild plants and animals by some prehistoric foragers (Henry 1989); (3) translocation of wild plants and animals by foraging groups and the management or cultivation of these wild species in some instances (Piperno and Pearsall 1998); (4) the initial domestication of plants and animals in several independent centers (Cowan and Watson 1992; Price and Gebauer 1995a; Smith 1998); (5) the adoption of these plants and animals by foragers living in adjacent regions, often in different habitats; (6) subsequent experimentation

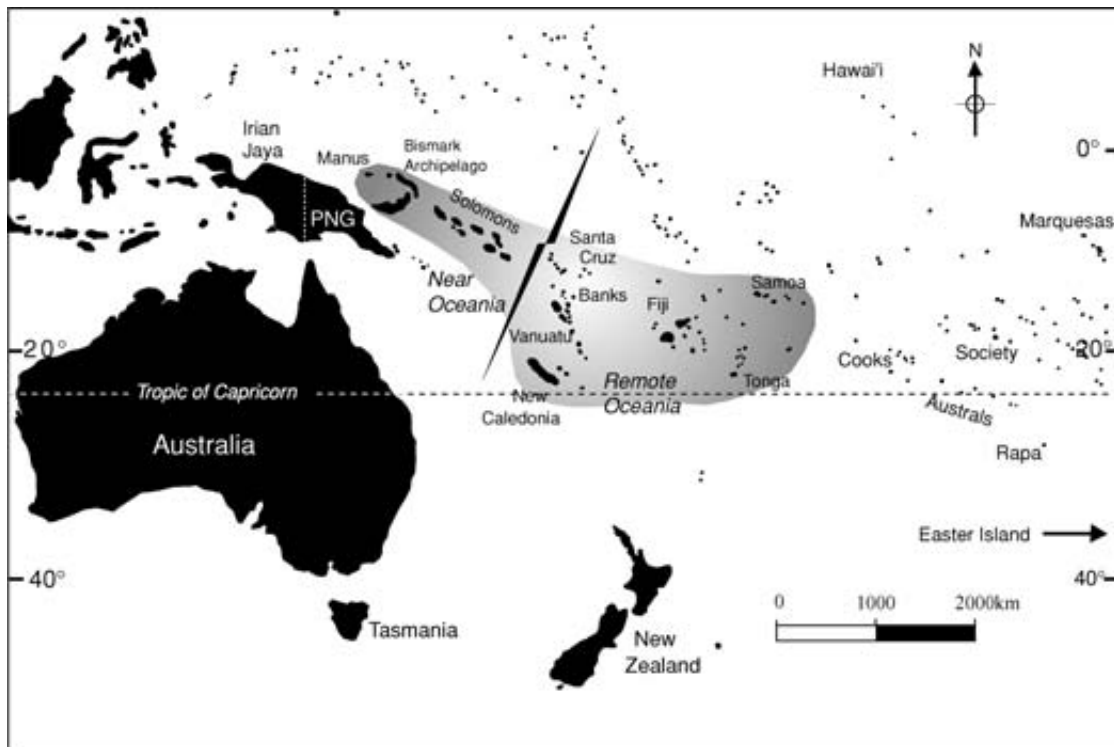


FIGURE 12.1. Map of Oceania showing the relevant islands and archipelagos.

leading to a reliance on food production or the stability of mixed subsistence strategies (low-level food production; Smith 2001a; Tucker, this volume); (7) continued transmission of new and improved domesticates through exchange networks (Hastorf 1999), and (8) the ultimate emergence of more intensive food production in certain locations (Smith 1998). Some of the consequences of food production included localized population growth, the spread of domesticated plants and animals along with agrarian knowledge and technology through exchange networks, the actual migration of food producers into regions occupied by foraging populations (Cavalli-Sforza 1996; Diamond and Bellwood 2003), and a general increase in human impacts on natural ecosystems (Bellwood 2001; Diamond and Bellwood 2003; Redman 1999). The demographic expansion of farming populations is linked to significant cultural, linguistic, and biological changes (Bellwood 2001). It has also been argued that the emergence of food production fostered the expan-

sion of anatomically modern humans into previously unoccupied territory, most notably the colonization of ever smaller and more remote islands in the Pacific, Mediterranean, and Caribbean (Diamond and Bellwood 2003; Keegan and Diamond 1987; Kirch 2000; Kirch and Green 2001; Patton 1996; but see Anderson 2003a).

In this chapter we explore the dispersal of people into Oceania and the role that food production may have played in this complex social and ecological process. In particular, we are interested in the migration of people onto islands in Near and Remote Oceania (Figure 12.1).¹ Near Oceania consists of several large islands in the Bismarck Archipelago, positioned 100–200 km to the northwest coast of New Guinea, and the Solomon Islands, a series of smaller islands that stretch to the southeast. Prior to sea-level rise during the late Pleistocene and early Holocene, the Solomons formed a single larger island known as Greater Bougainville. Vanuatu and New Caledonia

form the western boundary of Remote Oceania, which also includes 38 major archipelagos of 344 colonized islands in West and East Polynesia (Kirch 1984). West Polynesia encompasses the larger, aggregated archipelagos of Tonga and Samoa, plus some smaller archipelagos. In its early prehistory, Fiji is also regarded as West Polynesian. Except for New Zealand, islands in East Polynesia tend to be smaller and more dispersed.

All of the islands in Near Oceania lie within the tropics, but several islands in Remote Oceania are subtropical or are positioned farther to the south, and have temperate climates; for instance New Zealand lies between 35 to 45° south. Little seasonality in rainfall or temperature occurs close to the equator, but cooler temperatures and distinctive wet and dry seasons become more common to the south (Spriggs 1997; Anderson 2001a). The initial colonization of Remote Oceania involved a sixfold increase in minimum voyaging distances over those attained in Near Oceania (200 km) and distances of up to 3700 km were crossed to reach New Zealand and Hawaii.

The study of island colonization has a long history with a large body of literature developed during the last 30 years (Fitzpatrick 2004; Keegan and Diamond 1987). Much of this research was stimulated by MacArthur and Wilson's 1967 book entitled *The Theory of Island Biogeography*, and by the recognition that islands provide a well-bounded context for studying cultural evolutionary processes. In the late 1980s, Keegan and Diamond (1987) synthesized the literature on island colonization in various parts of the world and concluded that biogeographical principles, particularly their physical and geometrical properties, provided a useful framework for understanding the colonization process. They argued that climatic, geological, and oceanographic differences among islands shaped their terrestrial and marine productivity and influenced the ability of humans to colonize them. Superimposed on these ecological qualities are geometric properties influencing the likelihood that seafaring migrants will reach

particular islands—factors like position, size, and the distance between pairs along likely routes of colonization. In this view, the likelihood that an island will be colonized decreases with distance, as does the possibility of follow-up assistance once an island is occupied. However, colonization of distant islands may be promoted by configurational effects. For instance, archipelagos consisting of larger aggregations of islands potentially provide greater resource diversity for colonists compared with individual islands. Island size also influences the probability of successful colonization because larger islands offer a greater quantity and diversity of habitats and resources.

Although physical and geometric properties are important for understanding island colonization, purely biogeographical models have shortcomings. Based on the geometry of position, distance, and size, they highlight the probabilistic elements of “blindly” reaching a particular island and surviving there. They do not help to analyze the reasons for initiating migration, nor the intentional or unintentional consequences of settlement for an island's resource potential, and thus for the long-term persistence of settlement. Although likely to be important, such factors are extraneous to biogeographic models.

In Oceania, explanations for island colonization can be grouped into push or pull models. Most push models invoke demographic pressure as the primary causal force initiating dispersal (Clark and Terrell 1978; Anderson 1996). It has been argued that population levels on islands generally increase with agricultural intensification, and eventually the population exceeds carrying capacity, stimulating segments of the population to move to adjacent islands. Pull models often propose a rapid dispersal of people through Oceanic island chains, as opportunistic foragers skim off the highest-quality resources (Clark and Terrell 1978; Anderson 1996; Davidson and Leach 2001) and quickly move on to the next propitious location. Although an improvement, the combination of biogeographic patterning and push-pull variables

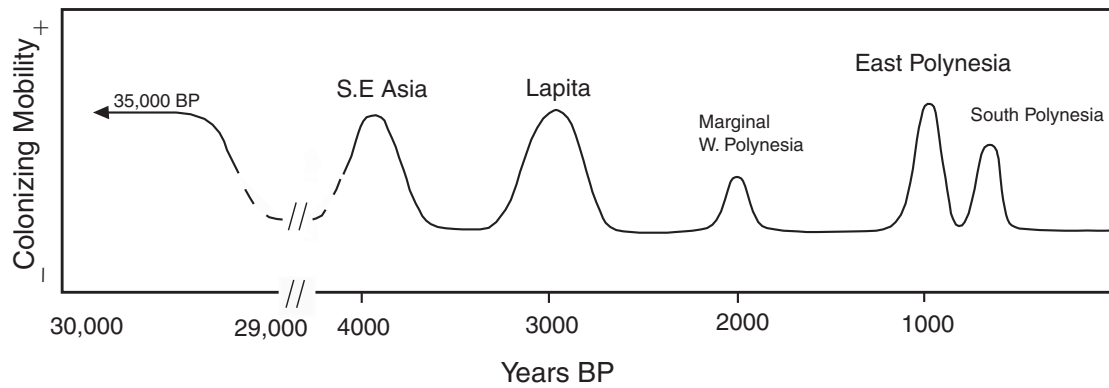


FIGURE 12.2. Colonization mobility in Oceania during the last 35,000 years (see Anderson 2001a).

does not capture the episodic nature of migratory behavior evident amongst humans and other animals (Diamond 1977), and evident in the archaeological data from Oceania (Anderson 2001b; Figure 12.2). Island colonization in Oceania also appears to be a dual phase process. Each episode seems to have a sedentary phase, perhaps representing a period of population growth, and a phase of high mobility and rapid dispersal. The speed of colonization during these unstable episodes does not suggest incremental demographic pressure, but is more reminiscent of rapid dispersal, triggered by opportunistic foraging behavior. It appears that a variety of contextual variables are at work; colonization of Oceania cannot be explained by invoking single variables.

In this chapter we develop an integrative, multivariate model for the colonization of Oceania within the behavioral ecology framework of the ideal free distribution (Abrahams and Healey 1990; Fretwell and Lucas 1970; Sutherland 1996). This set of ideas provides a simple framework that considers the dynamic character of habitat suitability along with density-dependent and density-independent variables that might influence dispersal and habitat selection by colonists in Oceania. In particular, we examine how food production might have influenced decisions to disperse and colonize remote islands. We argue that low-level food production (Smith 2001a), and later intensive food production, contributed to more rapid decreases in habitat suitability through degradation, but also

increased the overall carrying capacity of many remote island habitats. This particular point is set within a more general argument: low level and ultimately more intensive food production was one of several variables including population growth, dynamic impacts of exploitation on fragile island environments, technological development, and the inherent ecological suitability of various island groups in Oceania. The ability of human behavioral ecology (HBE) to integrate multiple contextual variables with an emphasis on behavioral responses to changing ecological conditions make it an ideal framework to explore the causes and consequences of human dispersal onto remote islands in Oceania.

IDEAL FREE DISTRIBUTION AND HUMAN MIGRATIONS

Two consequences of food production were localized population increase and the dispersion of agricultural populations into areas occupied by hunter-gatherers or regions not previously populated (Bellwood 2001; Diamond and Bellwood 2003). The migration of animals or people into new habitats often entails a series of complex behavioral responses to changing social and environmental conditions. Both density-dependent and density-independent influences may stimulate migration. Ultimately, an individual's or group's decision to migrate depends on the cost and likely success of relocating, and on the overall size, quality, and productivity of a home-

land region relative to alternatives elsewhere. The overall productivity and suitability of a region can change for a variety of environmental and social reasons. Short- and long-term climatic changes may alter the distribution and availability of subsistence resources, as will changing subsistence practices and technology such as foraging or food production, fluctuations in the density of the human occupants, habitat degradation due to unsustainable exploitation, and changes in social cohesion or conflicts. Dense populations often deplete resources rapidly, but low density use can affect the availability and distribution of other plant and animal species on which a population depends (Sutherland 1996). Resource exploitation also can entail mutualistic and beneficial relationships between humans, animals, and plants, for instance by enhancing the suitability and resource richness of an environment (Rindos 1984).

Another consequence of larger populations is competition that lowers the overall suitability of a resource patch or habitat. Conspecifics deplete shared resources; interference can result from fighting, stealing, or control of resources or patches by individuals (Sutherland 1996). Territorial or despotic behavior by individuals or groups may also affect the suitability of a region and can stimulate the movement of people into adjacent, less desirable areas. Warfare and despotic behavior would be expected in regions that were environmentally or socially circumscribed (Carneiro 1970, 1978, 1988). In this context, the largest populations would aggregate in the most productive locations. Population increases, from endogenous growth or in-migration, and community fission would result in the infilling of more marginal zones. In some instances this would result in environmental “packing” and decreases in habitat suitability (Binford 1968, 1983). In addition, the territories of some groups may extend well beyond their immediate needs, thus forcing disenfranchised individuals to colonize more marginal habitats. Contests for smaller, more circumscribed sections of arable land would predictably become more frequent within this context. Warfare and

other forms of despotic behavior (e.g., cannibalism; Kantner 1999) also create social instability and may stimulate the dispersal of people well below the actual carrying capacity of a habitat (Kennett and Kennett 2000). The net result of these despotic behaviors is reduced habitat suitability leading to more rapid emigration.

THE IDEAL FREE DISTRIBUTION (IFD)

The IFD model provides an explanatory framework for predicting when individuals will disperse or migrate to a new habitat based on density-dependent changes in the suitability of the habitats available to them. Habitats are ranked by their quality, as assessed by the fitness of the initial occupant. Typically, fitness-related measures such as production of young or rate of food intake are used to measure quality or suitability (see Winterhalder and Kennett, Chapter 1, this volume; Figure 12.3). Quality is density dependent and declining with increasing population density due to competition. Competitors may use up resources directly, for instance by occupying living sites or by consuming and depleting food resources, or they may indirectly make resources harder to find or capture; for instance, by stimulating their dispersal or elevated wariness; or render them less desirable by contaminating or fighting over them. The former is known as depletion competition, the latter as interference competition. Sutherland (1996, 9) gives this example: “drinking a pub dry would be depletion whilst a crowd around the bar hindering access would be interference.” In the case of the subsistence transition from foraging to food production, depletion would include density-dependent decreases in game animals; interference would encompass increases in erosion and the depletion of soil nutrients associated with more intensive land use.

For IFD purposes, a habitat is defined partly by scale—it is larger than the multiple patches that would be encountered in a single foraging trip and equal to or smaller than the whole range available to a group—and partly by economic characteristics—it is a relatively homogeneous zone of production with respect to the resources

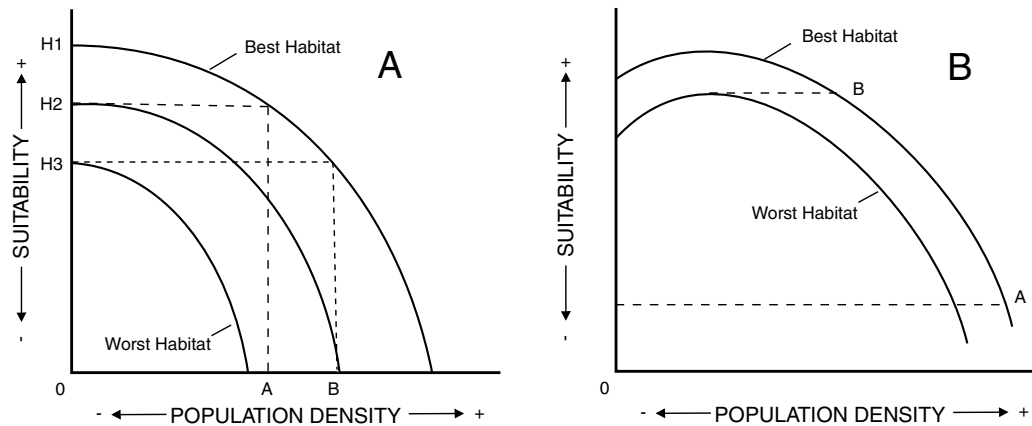


FIGURE 12.3. A) Ideal free distribution (after Fretwell and Lucas 1970, 24; Sutherland 1996, 5); B) Allee's principle (after Fretwell and Lucas 1970, 25; Sutherland 1996, 11).

available and a characteristic method of extracting them. Key to this definition: we expect each habitat to be characterized by a unique curve representing its suitability, as a function of increasing population density and exploitation. For instance, habitats in Oceania would include inland (initially forested), riverine, and coast (e.g. rocky shoreline, beach and reef). This definition recognizes that we may wish to analyze population distribution over contemporaneous, but spatially separate habitats. Or, the IFD can also be used to compare temporal shifts among the habitats that emerge on the same landscape if, for instance, climate change significantly alters its resource characteristics or a technological innovation provides a new means of exploiting the resources found there. The former would allow for the analysis of how a population distributes itself over a set of extant habitats; the latter would analyze choice with respect to “movement” to changing environmental or technological possibilities. Combinations are possible, and settlement of Oceania probably entailed both possibilities. In our very general IFD application we model two habitats defined by environment; small versus large islands, and two defined by shifting between modes of resource extraction; foraging versus food production (see below).

We assume that individuals will elect to reside in the *ideal* or best habitat available to them,

and that they are *free* or unrestricted in their movement to effect that choice. They are competitors of equal ability and access to resources. Under these conditions, habitat distribution will work out in the following manner. Colonizing individuals will locate first in the best habitat available. With increasing density due to immigration or to *in situ* growth suitability there drops. When it is diminished to the quality level of the second ranked habitat, further population growth stimulates immigration and populations will become apportioned between them. Because each individual is ready to relocate if another habitat offers an edge in suitability, the population distribution will equalize marginal qualities across all occupied habitats. This is an equilibrium distribution, a consequence of the marginal equalization of habitat suitability. At the IFD no individual has an incentive to relocate.

The IFD makes two general predictions: (1) the extant population distribution over available habitats will reflect an equilibrium that equalizes their marginal suitabilities; and, (2) the chronological sequence of habitat occupation and use; changing densities in a particular habitat; changes in the variety of habitats occupied will follow the pattern predicted by a particular form of the IFD curves (see Sutherland 1996, 1–14). In each case, empirical tests of

quantitative predictions provide stronger results than qualitative assessments. Our application focuses mainly on a corollary of (2): continuous change in overall population size will result, by IFD predictions, in a process of habitat settlement and migration with important *discontinuous* properties. In particular, migration from larger islands should be more episodic than from smaller, and migration from agricultural populations more discontinuous than from foraging populations. Our evidence is meager and mainly qualitative, but the effort is interesting because no other model of comparable generality makes predictions consistent with the episodic character of human occupation of Pacific islands.

THE DESPOTIC VARIANT

The ideal despotic distribution (IDD) is a variant of the IFD highlighting differential access to resources. If interference arises among competitors of unequal abilities, or if by establishing territories, initial or superior competitors can protect themselves from density dependent habitat deterioration by successfully defending better resource opportunities, then the inferior competitors and those without territories are pushed to poorer habitats. Compared to the IFD, a despotic distribution will equilibrate with disproportionate numbers or densities in the lower-ranked habitats. This makes intuitive sense: by garnering disproportionate resources in the best habitats, the better competitors push their inferiors into habitats of lesser suitability. Because of this, the use of lower-ranked resource patches has been documented as a buffering strategy among a variety of bird species (Brown 1969; Meire and Kuyken 1984; Moser 1988). In fact, in empirical studies the ideal free distribution sometimes serves as a null hypothesis to measure the effects of interference competition and unequal resource access (Sutherland 1996).

THE ALLEE EFFECT VARIANT

There also may be density-dependent effects within habitats that make their suitability *increase* over some range of increasing population density. At very low population densities the

overall survival rate may be low because of the difficulties associated with finding mates or problems with inbreeding depression (Allee et al. 1949; Sutherland 1996). Increasing density improves the suitability of the habitat for subsequent arrivals. Likewise, the subsistence system may be affected by positive economies of scale, where scale is determined by density. A growing population might increase the density of desirable resources by more completely maintaining forest cover in early stages of succession. It might facilitate technological improvements, from seed distribution to irrigation. The suitability of marginal areas might be improved once colonized, as forests were cleared and fields were prepared through plowing and terracing. Greater density may also offer protection from intruders or enemies.

Figure 12.3b shows the distributional consequences of the Allee effect. As before, initial settlement populates the highest ranked habitat, A. Whether from *in situ* growth or external immigration, increasing density eventually spills over into habitat B. However, because the suitability of habitat B *increases* with each addition, it draws population from habitat A, reducing density there. If the apex of the suitability/density curve for habitat B is higher than that for habitat A, and B is sufficiently spacious, the Allee effect conceivably will empty habitat A for a period, as individuals seeking a more salubrious habitat quickly migrate to this new and improving zone. Habitat B would show a rapid increase in population; the decline in habitat A could be quite dramatic. With an Allee effect, individuals might abandon areas that previously provided adequate payoffs, a pattern consistent with settlement unconformities evident in several parts of the world as agricultural populations replaced or subsumed hunter-gatherer populations (Bellwood 2001; Renfrew and Boyle 2000).

Whatever form it takes, the IFD shows how an incremental quantitative change in one variable such as population density or habitat suitability may lead to qualitative changes in another; the range of habitats occupied; their relative

settlement densities. Moving from the IFD to the IDD and Allee variants portends qualitative changes of increasing magnitude. As with most HBE models, there are few limits on what kinds of variables one might accommodate in the IFD and its variants. For instance, climate change might shift the relative suitability (vertical position, thus relative ranking) of the curves. Habitats or subsistence practices highly susceptible to density dependent degradation will have steep downward slopes; those which generally are not so sensitive to population density will have more shallow slopes. Economies of scale in subsistence practice may cause the slope of the curve to be positive over certain ranges of density. The consequences of territoriality, social inequality, and economic exploitation for dispersion and habitat use can be represented in despotic versions of the model. Manipulation of these and other elements can be used to generate hypotheses about population distribution and migration based on a wide range of potentially causal conditions.

The IFD model does not explicitly include the cost of relocation, assuming that this is negligible when compared to the benefits of optimizing long-term habitat choice. This simplification is expedient for analytical purposes, but it may seem an especially unrealistic assumption in the case of initial spread over broad expanses of the Pacific. The issue here, however, is relative rather than absolute costs of relocation which can be thought to constitute a continuum broadly divisible in two. First, most of the islands in Remote Oceania, like those in Near Oceania, lie at distances which could be covered in a week or less of sailing, and it can also be argued (Anderson 2003b) that predictability of finding new islands was quite high within the main island band of the tropical south Pacific. Given the same sailing technology and a choice of favorable sailing conditions, the relative cost of relocation was small. Second however, there were some passages that were unusually long within the main band of Remote Oceanic islands, as between Vanuatu and Fiji,

or Samoa and the Cook Islands, and in addition there were several very long passages to the marginal islands of Hawaii, Easter, and New Zealand. Clearly the costs of relocation in these cases, especially to the margins, must have been higher than was common within the main island band. How much higher depends in part on what view is adopted of maritime technology. If Polynesian vessels and navigation were of a high order of capability (Finney 1979; Irwin 1992; Lewis 1994), then relocation costs to the margins must have been substantially lower than if the technology was relatively undeveloped (Anderson 2000a). On the other hand, the issue is also a perceptual one. Groups considering relocation in circumstances where the preferred choice was to sail off into the unknown had no way of estimating the relative cost of reaching a new island, and it is possible that, within the initial period of dispersal, the perceived relocation cost flattened to virtual invariance everywhere beyond the islands of an already-settled archipelago. Of course, when voyaging occurred after the period of initial dispersal, by which time some sense of Oceanic geography may have developed, then relocation costs could more reliably be factored into choices. An additional issue is the degree to which relocation might have generally coincided, or was not prompted by, periods of wind reversal on a millennial scale; in which case a high frequency of downwind sailing would also have reduced the relative costs of relocation (Anderson, n.d.b). These considerations are, as yet, inadequately researched, but relative insignificance of relocation costs can be assumed in the interim for the sake of exposition here.

As will become evident in the following sections, the islands of Oceania were colonized over a long period of time by people using a wide range of subsistence practices, from foraging to intensive food production. The size and productivity of these islands also varies greatly, from the large, more tightly clustered islands of Near Oceania to the smaller, more dispersed islands of Remote Oceania. As a starting point for

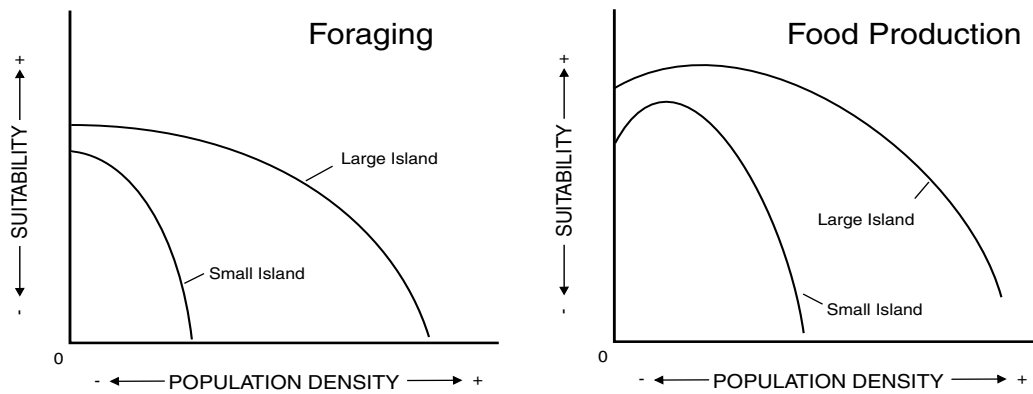


FIGURE 12.4. Hypothetical IFD models for mobile foraging and food production on small and large islands.

generating predictions, we distinguish between IFD curves for foragers and food producers, and those for large and small islands (Figure 12.4). The hunter-gatherer curves are negatively sloped reflecting population-dependent impacts on habitat productivity. On small islands they decline steeply and approach the x-axis at fairly low population sizes; on large islands they decline more gradually and approach the x-axis at significantly larger population sizes. By contrast, the food-producer curves evidence an Allee effect due to economy of scale and peak, before declining. On small islands the peak is fairly narrow and the plunge to the x-axis occurs at low population size; on large islands the peak is high and broad and the approach to the x-axis at quite large population sizes. Consistent with the observation that the earliest forms of food production were probably less efficient than foraging, at its best, we have ranked the initial suitability of food-production “habitats” below those for foraging in the same environment whether large or small island. We do not depict despotic behavior leading to resource defense, but it would put pressure on weaker competitors to emigrate by promoting more rapid plunges towards the x-axis, thus stimulating rapid dispersal.

The proposed set of IFD models allows us to more precisely predict episodes of colonization as a function of population density and mode of production. Specifically, hunter-gatherers are

more likely to be mobile, and the pace of colonization likely to be more regular and more dependent upon island size. Food producers are likely to be less mobile, and the pace of colonization more episodic. This is because the Allee effect creates a period of “stickiness” to a new settlement, in which things are actually improving with increases in population size, negating any tendency for significant emigration in a new round of colonization for some time period. That delay will be longer the larger the island. Regardless of island size and mode of production, one of the most robust predictions of this model is that if habitats vary in terms of average rewards, then migratory behavior is expected to be episodic rather than continuous. Because this appears to be the pattern of migration in Oceania, a pattern not easily accommodated in alternative explanations, we believe the IFD may have explanatory merit. Our argument requires that we turn to Oceania, first to the specifics of island colonization and second to temporal changes in subsistence practices.

COLONIZATION OF OCEANIA

Archaeological evidence shows that the first pulse of colonization into Oceania was initiated during the Pleistocene Epoch between 35,000 and 29,000 years ago (see Figure 12.2).² These early colonists likely departed from the

northeastern coast of New Guinea to occupy New Britain and New Ireland, the largest islands in the Bismarck Archipelago (Allen et al. 1988; Allen et al. 1989). Adjacent islands exhibiting evidence for Pleistocene age settlement include Buka, on the northern end of the Solomon Island chain, and Manus, positioned 200 km northeast of New Ireland (Fredrickson et al. 1993; Wickler and Spriggs 1988). During much of the Pleistocene, sea level was substantially lower than today and New Guinea was connected to Australia forming a super-continent known as Sahul. Anatomically modern humans colonized this landmass from Southeast Asia by at least 40,000 years ago (Allen 1994; Allen and Holdaway 1995) and perhaps as early as 55,000 B.P. (Roberts et al. 1994; Thorne et al. 1999). The crossing from Southeast Asia (also a landmass less insular and more extended by lowered sea levels, known as Sunda) to Sahul suggests that people had some rudimentary seafaring technology at this early time (Anderson 2000a; Clark 1991; Erlandson 2001).

Colonization of the Bismarck archipelago and adjacent islands by hunter-gatherers depended on the appropriate maritime technologies and knowledge (Irwin 1992). Given the close geographic proximity of these islands to New Guinea, however, relatively simple boats, even bamboo rafts, some of which occur naturally after floods, could have been used (Anderson 2000a). It is very unlikely that sails were employed as Horridge (1987) has proposed, because sailing technology worldwide has a mid-Holocene origin, including in China, one of the more likely sources of Pacific technology (McGrail 2003). The accessibility and suitability of some islands was also enhanced by lower sea-level stands in the Pleistocene. Between 35,000 and 29,000 years ago sea level was 40 and 70 m below current levels (Thorne and Raymond 1989). New Britain, New Ireland, and Manus were larger, but the water gaps between New Guinea and the Bismarcks were essentially the same. New Britain is visible across the 90 km gap separating it from New Guinea and there is two way intervisibility (<100 km) between all of

the islands in the Bismarck archipelago except for Manus. This island is ~230 km from New Ireland and required a blind crossing of 60–90 km (Spriggs 1997). However, it is unclear how early in the Pleistocene Manus was colonized due to the absence of datable material at the base of Pamwak, the only Pleistocene-age site known on the island (Fredericksen et al. 1993). The island of Buka, in the Solomon archipelago to the south, was also colonized early (29,000 B.P.; Wickler and Spriggs 1988) and required a partially blind crossing of 175 km from New Ireland. At this time, Buka was the northern extent of a single island known as “Greater Bougainville” that extended southeast through the modern day Solomon Island chain. There is currently no evidence for colonization of Vanuatu or New Caledonia, or other more remote archipelagos, until after 3300 B.P. (Anderson et al. 2001a).

The next significant episode of island colonization in Oceania appears to be associated with the expansion of agricultural populations south from Taiwan through the islands of Southeast Asia between 5000 and 4000 years ago. This spread of people is inferred from the widespread distribution of archaeological assemblages containing Asian domesticates—the ubiquitous rice, pigs, and dog; red-slipped or paddle impressed pottery; ground stone adzes; distinctive shell and bone ornaments; and bark-cloth beaters (Bellwood 1975, 1978, 1985, 1996, 2001). Biological and linguistic data suggest that the changes evident archaeologically were related to an expansion of Austronesian-speaking people that ultimately replaced or swamped the existing hunter-gatherer populations on each island (Diamond and Bellwood 2003). The appearance of ceramics in archaeological assemblages in the Bismarcks at 3300 years ago has also been interpreted as an extension of this expansion (Bellwood 1978; Shutler and Marck 1975; Spriggs 1990)—an intrusion into island Melanesia of new people with different subsistence regimes, settlement practices, and sociopolitical organization, known as the Lapita cultural complex in Melanesia and Polynesia. However,

other scholars interpret the appearance of Lapita as the product of *in situ* developments within Island Melanesia (Allen and White 1989; Gosden 1992; Gosden and Specht 1991; Terrell 1989; White et al. 1988; see below).

Lapita-age settlements of 3300 to 2300 B.P. are identified by the presence of dentate-stamped or incised pottery (Anderson et al. 2001a; Kirch 1997). A recent inventory of archaeological deposits containing dentate-stamped pottery includes approximately 184 locations extending 4500 km from the Bismarck Archipelago, southeast to Fiji, Tonga, Samoa, and Wallis in the South Pacific (Anderson et al. 2001a; see Figure 12.1). The appearance of Lapita pottery east of the Solomon Islands represents the earliest known colonization of Remote Oceania (Kirch and Hunt 1988). Sites throughout the Lapita range are most commonly found in coastal contexts with overall densities on larger islands being lower than smaller islands (Anderson 2001a). If the frequency of Lapita sites is standardized using land area by island size, the number of Lapita sites in Near Oceania (1.74 per 1000 km²) is virtually identical to Remote Oceania (1.69 per 1000 km²), but within Remote Oceania the overall density of sites increases from west to east (1.24 per 1000 km² in Vanuatu/New Caledonia to 2.45 per 1000 km² in Fiji and West Polynesia; Anderson 2001a).

Although there are similar densities of Lapita sites in Near and Remote Oceania, the chronological range of these sites throughout the region is quite different. Recent dates from the Bismarck Archipelago suggest the appearance of Lapita pottery at around 3300 B.P. with the cessation of production occurring as late as 2000 B.P. (Anderson 2001a; Green and Anson 2000; Specht and Gosden 1997; Torrence and Stevenson 2000). Dates range between 3100 and 2600 in the Reef/Santa Cruz Archipelago; 3000 to 2700 B.P. for Vanuatu (Bedford et al. 1998; Spriggs 1997); 3000 to 2700 for New Caledonia (Sand 1997, 1999; 2000); 2900 to 2600 B.P. for Fiji (Anderson and Clark 1999); and 2850 to 2650 B.P. for West Polynesia (Tonga, Samoa and Wallis). These data suggest

a 200–400 year lag between the initial settlement of Near Oceania and the first dispersal of people into portions of Remote Oceania. It also appears that colonization accelerated from west to east and that the persistence of the Lapita cultural complex was more fleeting in Remote Oceania (Anderson 2001a). When the overall number of sites is considered in Near and Remote Oceania, settlements were established much more rapidly in Remote Oceania (22–27 per century) when compared to Near Oceania (6–10 sites per century) (see Anderson 2001a and Anderson et al. 2001a).³

Recent archaeological studies suggest a long pause of perhaps 1500 years between the expansion of Lapita peoples into West Polynesia and the colonization of more remote islands and archipelagos in East Polynesia (Anderson 2002; Anderson and Sinoto 2002). New work in the Society Islands suggests colonization no earlier than 1000 B.P. (Anderson et al. 1999) and the current data from the Marquesas indicate early settlement dating to around 900 B.P. (Rolett and Conte 1995; Rolett 1998). On the remote fringes of East Polynesia, Easter Island was likely colonized by 1000 B.P. (Steadman et al. 1994), Hawaii at about the same time (Athens et al. 1999), and New Zealand (Anderson 1991, Higham et al. 1999) along with several other south Polynesian islands (Anderson and White 2001; Anderson and O'Regan 2000; Johnson 1995) by 800 B.P. We currently are reevaluating the early settlement history of Rapa in the Austral Islands, but it is likely that this remote island was settled no earlier than 800 B.P. (Kennett et al. 2003; Walczak 2001). Colonization of East Polynesia also includes the 25 “mystery islands” (e.g., Christmas, Norfolk, and Pitcairn Islands), colonized after 1000 B.P., then abandoned before European contact (Anderson 2001b, Anderson et al. 2002; Bellwood 1978). Thus, the data indicate that the colonization of East Polynesia was late and, despite vast geographic expanse, relatively rapid.

These new settlement data do not support the traditional view that eastward voyaging and

colonization were relatively continuous once they were initiated by Lapita peoples (Kirch 1997, 2000; Irwin 1992). The idea that colonization was continuous has been supported by decreases in indigenous tree pollen and increases in charcoal sediments in a paleoenvironmental sequence collected from Mangaia in the Cook Islands interpreted as anthropogenic forest clearance starting as early as 2500 B.P. (Kirch 1996, 1997, 2000). Similar types of sequences have been used to argue for early settlement on Easter Island (1500 to 1200 B.P.; Flenley 1996; Parkes 1997; Parkes and Flenley 1990) and New Zealand (2000 to 1500 B.P.; Sutton 1987). However, recent studies in New Zealand suggest that ancient soil carbons are often washed into lake sediments and return anomalously old radiocarbon dates (McGlone and Wilmshurst 1999). Therefore, the lake core chronologies from Mangaia and elsewhere are suspect and should be carefully reevaluated. Furthermore, there is often a dichotomy between lake core data suggesting anthropogenic landscape modification and the earliest tangible archaeological evidence for colonization. For instance, Kirch (1996) excavated seven rock shelter sites on Mangaia and has a well-established chronology (40 radiocarbon dates) for human activities on the island starting at approximately 1000 B.P. Interestingly, the earliest levels of the Tangatatau Rock shelter site (~1000 B.P.) contained the bones of several extinct landbirds and these species do not appear in more recent strata at this or other sites on the island, suggesting the prehistoric extirpation of these species (Steadman and Kirch 1990). The presence and rapid extirpation of large landbirds (~200–300 years after colonization; see below) is consistent with other early settlement sites in East Polynesia (Anderson 2002). Based on these data we would argue that the deposits at Tangatatau Rock shelter represent some of the earliest settlement on Mangaia. Again, this is consistent with new evidence from elsewhere in East Polynesia (e.g., Anderson and Sinoto 2002) and our central thesis that colonization of the Pacific was episodic. We now turn to a more detailed analysis

of subsistence strategies and the emergence of food production in Oceania.

SUBSISTENCE CHANGE AND THE ORIGINS OF FOOD PRODUCTION

The first people to colonize Near Oceania between 35,000 and 29,000 years ago were probably relatively mobile hunter-gatherers whose subsistence strategies were structured by the availability and distribution of wild foods. Terrestrial fauna were restricted to a narrow range of edible species that included lizards, snakes, rats, bats, and birds (Spriggs 1997), but coastal habitats like reefs and lagoons offered a rich array of marine foods (Flannery 1995). The tropical forests covering these islands provided little in the way of edible plant foods, but disturbed patches along rivers and coastlines, particularly wetlands, would have afforded staples familiar to early colonists (taro-*Colocasia esculata*; and sago palm, *Metroxylon*) (Spriggs 1997; Yen 1985, 1995). Forest disturbance and habitat manipulation during early settlement would have promoted the growth of these wild plants (Groube 1989; Yen 1995).

Evidence for settlement in Near Oceania prior to 20,000 years ago is relatively scarce. Only four sites can clearly be assigned to this early period (Spriggs 1997). Three of these sites are pericoastal rock shelters or caves that contain stratigraphic evidence for sporadic use during this early period (Allen 1991; Gosden and Robertson 1991). Simple flaked stone tool assemblages at these sites also suggest high mobility. Marine shells and fishbone are the most common constituents in these deposits. At the sites of Buang Meraback and Matenkupkum (New Ireland), the large size of shells suggests that the early inhabitants of this cave were foraging in relatively pristine shell beds (Spriggs 1997). The fishbone found in the lowest levels of Matenkupkum is also some of the earliest evidence for marine fishing in the world (~35,000 B.P.; Allen 1993). Ueware and starch grains on stone tools from Kilu Cave on Buka Island (Solomons) suggest that maritime foraging was

coupled with plant exploitation, including the use of *Colocasia* taro, a plant that later became an important agricultural staple in Melanesia and Polynesia (Loy et al. 1992). The importance of plants to these early colonists is also suggested by the open air site of Yambon, positioned in the forested interior of New Britain (Pavlidis 1993; Pavlidis and Gosden 1994).

Changes in settlement and subsistence in Near Oceania after 20,000 years ago are signaled by a break in the occupation of pericoastal rock-shelters. The caves and rock-shelters used after 20,000 B.P. are positioned 3–5 km from the coast at a slightly higher elevation (Spriggs 1997). Marine resource exploitation continued, but changes in shellfish assemblages are evident, particularly between sites occupied during the late Pleistocene and early Holocene. Some of these changes are easily attributed to habitat changes coincident with sea level rise or the formation of coastal estuaries associated with the stabilization of sea level between 8000 and 6000 B.P. (Spriggs 1997). Other changes in marine shell assemblages are attributed to intensified human exploitation strategies, their impact on intertidal resources, and subsequent adjustments of foraging strategies. For instance, when the Holocene (10,000 to 2000 BP) assemblages at Matenkupkum (New Ireland) are compared to the pre-20,000 deposits, a much wider range of small and large species are evident and the quantities of the largest species are significantly reduced (Gosden and Robertson 1991). A similar pattern is evident at Buang Merabak where an increased variety of smaller shell taxa are evident after 10,800 BP (Balean 1989; cited in Spriggs 1997). These patterns are consistent with heavy exploitation and depletion of high ranking resources and the consequent expansion of diet breadth, also documented by Anderson (1981, 1983) in New Zealand, Broughton in late prehistoric Northern California (Broughton 1999), Janetski in the Great Basin (Janetski 1997), and others (Butler 2000; Nagaoka 2001, 2002).

The fishbone collected from late Pleistocene and early Holocene deposits suggests contin-

ued exploitation of near-shore reef habitats but there is little evidence for intensified fishing after 10,000 B.P. A small number of shark teeth found in Holocene deposits (8400 B.P.) at the Balof 2 rock shelter in New Ireland provide weak evidence for fishing beyond the reef (White et al. 1991). There is substantial evidence for deliberate movement of wild animals from New Guinea to the Bismarcks and Solomon Islands during the late Pleistocene, followed by more intensive hunting of these animals during the terminal Pleistocene and early Holocene (Gosden 1995; Flannery and White 1991). Evidence from several rock shelter sites indicate the late Pleistocene introduction of a possum species (*Phalanger orientalis*) to New Ireland from New Guinea (Flannery 1995). A different possum species (*Spilocuscus kramer*) was introduced to the more remote island of Manus (Bismarck Archipelago) and evidence for the introduction of the bandicoot (*Echymipera kalubu*) and a small wallaby (*Thylogale browni*) comes from caves in New Ireland (Flannery 1995). In addition, a rat species native to New Guinea (*Rattus praeto*) has been discovered in 13,000-year-old deposits at the site of Panakiwuk, New Ireland (Flannery 1995). What appears to be the deliberate translocation of animal species to Near Oceania suggests that people may have been compensating for population density-dependent resource depletion with the introduction of new species (Anderson 2001a).

A similar pattern is evident in the floral records from early sites in Near Oceania. The presence of native almond seeds (*Canarium indicum*) in late Pleistocene and early Holocene sites in Near Oceania indicate the transplantation of this species from New Guinea where it is naturally widespread (Yen 1990), although whether by people or the flying fox, remains uncertain (Anderson n.d.a). Seeds in terminal Pleistocene (13,000 to 10,000 B.P.) deposits at Pamwak (New Ireland) and Kilu (Solomons) might suggest early arboriculture, in essence the deliberate planting, tending, and harvesting of trees (Spriggs 1997). Evidence for short-term forest clearance during the Early Holocene is

visible in pollen records from New Ireland (Allen et al. 1989). *Colocasia* taro residues are evident on tools from late Pleistocene and early Holocene deposits and yam (*Dioscorea*) residues are present on two tools from the Holocene levels at Balof 2 (New Ireland; Barton and White 1993). This indicates continued low-level use of starchy plants from the Pleistocene into the Holocene.

There is also some evidence in Island Melanesia for the intensification of subsistence strategies during the Holocene. Pollen and charcoal evidence from several locations indicate short-term local clearance of forest and continuous, low-level burning in some areas. Shell and bone accumulations increased during the Holocene at the sites of Pamwak on Manus and formal artifact types, including shell and edge-ground stone axes, become more common (Spriggs 1997). A similar pattern is evident at the sites of Matenbek (New Ireland) where larger amounts of imported obsidian are symptomatic of intensified trade (Gosden 1995). Heightened exploitation of possum is also evident at several locations during the Holocene possibly providing the foundation for more stable, sedentary settlement at some inland locations (Marshall and Allen 1991; White et al. 1991). Several cave sites were also abandoned between 6000 and 5000 B.P. perhaps signaling reduced mobility and the consolidation of populations on the landscape. Wood structures found in the waterlogged deposits at the Apalo site (Arawe Islands) suggest a settlement stability at some locations between 4250 and 4050 B.P. (Gosden and Web 1994). These deposits also contained a large variety and quantity of seeds from trees (*Canarium*, coconuts, and others; Hayes 1992, cited in Spriggs 1997). Whether that suggests only an accumulation of shoreline flotsam in the waterlogged site (Matthews and Gosden 1997), systematic collection of naturally grown resources, or more formal arboriculture still remains uncertain. The predominant subsistence-settlement pattern evident in the records from across Near Oceania from 20,000 to 3300 B.P. is that of a mobile hunter-forager

strategy with some degree of localized intensification and sedentarization during the Holocene (Spriggs 1997).

By contrast, substantial changes in settlement and subsistence are evident in Island Melanesia after 3300 B.P. (Kirch 1997; Summerhayes 2000a). Pottery, including dentate stamped Lapita forms, appears in the record for the first time (Kirch 1997, 2000; Spriggs 1997; Summerhayes 2000a). New settlements were established on small, offshore islands and stilt houses were sometimes constructed over coastal lagoons. These communities were commonly larger than previously occupied residential bases (Anderson 2001a). Accelerated erosion evident in the geomorphological records surrounding these settlements is consistent with intensified gardening activities on adjacent hillslopes. The first undisputed appearance of domesticated animal bone of pig, chicken, and dog also occurs in these deposits (Spriggs 1997). The changes evident in the archaeological record are interpreted by some as a culmination of intensified subsistence practices in Island Melanesia during the Holocene (Allen and White 1989; Gosden 1992; Gosden and Specht 1991; Terrell 1989; White et al. 1988). Others (Green 1991; Kirch 1997, 2000; Spriggs 1997) hypothesize that these changes represent an influx of people and culture from island Southeast Asia, broadly linked with the Austronesian expansion out of China (Bellwood 2001, Diamond and Bellwood 2003). This hypothesis is supported by a variety of archaeological, linguistic, and genetic evidence (Bellwood 2001; Kirch 1997; Spriggs 1997); however it is likely that cultural developments during this time were complex involving intrusion, accommodation, integration, and innovation (Green 1991).

Spriggs (1997; Jones and Spriggs 2002) has described the early Lapita populations in Near Oceania as “full blown” agriculturalists, but the importance of food production is debatable based on the available data—particularly during the early stages of this cultural period. Lapita age sites (3300 to 2200 B.P.) in Near Oceania are commonly positioned on the coast near lagoons

or close to natural openings in island-fringing reefs. Shells and fish bones preserved in these sites suggest the exploitation of fish and shellfish from a variety of marine habitats: coastal lagoons, reefs, and open ocean. Artifact assemblages contain fishhooks, lures, and netweights, the technology of relatively sophisticated fishing practices (Summerhayes 2000a). Food production is inferred from geomorphological studies showing increased erosion rates near Lapita age settlements (Spriggs 1997), presumably associated with deforestation and field preparation for taro and yams in hillside gardens, but such data are difficult to interpret because forest clearance can occur in the absence of food production (e.g., clearing for settlement; Anderson 1995, 2000b). Beyond these data, building a case for intensive food production is difficult due to preservation problems in tropical environments. Waterlogged sites in Island Melanesia—Mussau and Arawes Islands (Kirch 1989; Gosden 1992)—provide some evidence for the utilization of nuts, and possibly of arboriculture based on the presence of *Canarium* and coconuts, but evidence for taro, yams, breadfruit, and bananas are absent. Forest clearance and a form of “swidden” horticulture may be indicated by increased charcoal concentrations in sediment cores after 3000 B.P. Changes in pollen assemblages also indicate a decline in tree taxa and the Lapita adze kit may have been used to ring trees and clear forest. Pig, chicken, and dog bones are all found in Lapita faunal assemblages, but all domestic animal bone occurs in much lower proportions relative to undomesticated species—particularly fish. For instance, at the waterlogged site of Talepakemalai eighteen pig bones were identified in a vertebrate assemblage consisting of 14,148 bones (Kirch 1997).

Several scholars have argued that the colonization of more remote archipelagoes in the Pacific—Vanuatu, New Caledonia, Fiji, Tonga, and Samoa—was significantly dependent on agriculture (Kirch and Green 2001; Spriggs 1997). Indeed, evidence for rapid colonization of more remote islands between 3200 and 2700 B.P. is used as one line of evidence supporting

the hypothesis that Lapita peoples had a well-developed food production economy (Spriggs 1997). It is true that terrestrial resources on islands east and south of the main Solomons are depauperate compared with the islands of Melanesia that were colonized during the Pleistocene. Indigenous land mammals are absent except for several species of bat. Large flightless birds were common on many of these more remote islands, but the overall diversity of avifauna was reduced. Plant diversity is also restricted in remote Oceania, and wild taro (*Colocasia* or *Cyrtosperma*), yams (*Dioscorea*), and bananas are absent (Green 1991; Spriggs 1997; van Balgooy 1971). With respect to Vanuatu, Spriggs (1997, 41) argued that, in the absence of domesticated plants and animals, human settlement may have been impossible, from which it was inferred that “transported landscapes” composed of taro, bananas, native almonds, breadfruit, pigs, chickens, and dogs carried in the canoes of early colonists were vital and allowed them to replicate their homeland economies (Kirch 1997).

The importance of food production to these early colonizing populations in Remote Oceania is largely hypothetical and not securely demonstrated (Anderson 2000b; n.d.a; Anderson and Clark 1999, Burley et al. 2001; Clark and Anderson 2001). Lapita settlements in Remote Oceania are generally positioned on old beach surfaces close to fringing reefs and lagoonal environments that provided a wide range of marine resources and clearly supplied the bulk of the diet (Kirch 1988; Burley 1998; Galipaud 1996). The size of these communities in Remote Oceania generally is smaller than equivalent sites in Near Oceania and settlement mobility appears to have been relatively high (Anderson 2001a; Clark 1999; Bedford et al. 1998, 1999). Similarly to Lapita assemblages in Near Oceania, marine vertebrates and invertebrates are common. Diverse kinds of fishing tackle, such as fishhooks and lures, point to the importance of maritime subsistence activities (Kirch 1997). Early Lapita deposits also contain terrestrial birds and reptiles that rapidly went

extinct (Anderson 2002). Early colonists in Vanuatu focused on harvesting naturally occurring foods that resulted in localized resource depletion and frequent site relocation (Bedford et al. 1998). In New Caledonia, the early animals targeted and extirpated included a large megapode (*Sylviornis neocaledoniae*), a crocodile (*Mekosuchus inexpectus*), and a horned tortoise (*Meiolania* sp.) (Balouet and Olsen 1989; Balouet 1987; Sand 1996a, 1997). Similar faunal extinctions are evident in Fiji where there was another giant megapode (*Megavitiornis altirostris*) and another genus and species of mekosuchid crocodile (*Volia athollandersoni*; Anderson et al., 2001b, Molnar et al. 2002, Worthy 2000; Worthy et al. 1999). Likewise in Tonga, there were large, now extinct, iguanids (Pregill and Dye 1989; Steadman 1993). Animal extinctions were a product of direct hunting and habitat destruction, but all of the known species seem to have gone extinct before there could have been any serious competition with introduced domestic and non-domesticated (e.g., rats) animals.

Only chicken bone appears in reasonably early Lapita contexts in Remote Oceania, and even there it might not have arrived with the first settlers (Steadman et al. 2002). Carbonized plant remains are rare in Remote Oceanic deposits, and no cultigens are known from early Lapita contexts. The presence of garden snails (*Lamel-laxis gracilis*) could provide early evidence for food production because it is a species that was probably translocated to Remote Oceania with taro planting stocks and associated soils (Kirch 1997). However, there is no evidence to show how early that might have occurred in the Lapita era. In addition, recently acquired and more firmly dated pollen and charcoal records from islands in Remote Oceania also suggest that food production played only a minor, if any, role initially (Anderson 2002). These newer records are starting to show a lag of up to 500 years between the appearance of burning and forest clearing activities for cultivation and the accelerated deforestation indicative of more intensive food production. In New Caledonia, where early Lapita sites date to between 3000 and 2900 B.P. (Sand

1997), charcoal levels in sedimentary cores increased after about 3000 B.P. and the diversity of tree pollen was reduced. However, large-scale deforestation is not evident in these records until 2500 B.P. (Stevenson 1999; Stevenson and Dodson 1995). A similar pattern is evident at several locations within the Fijian archipelago, sometimes coincident with evidence for increasing erosion (Anderson 2002).

Therefore, the case for early Lapita food production rests solely upon linguistic reconstruction (Kirch and Green 2001). Linguists have traced the root of modern Polynesian languages back to a proto-Oceanic language. Proto-Oceanic words for many of the domesticated plants, including taro, yam, banana, and breadfruit, and for aspects of the swidden agricultural system both suggest that food production has a long history in Oceania (Kirch 1997). These linguistic data, although intriguing, do not carry sufficient chronological precision, however, to validate the idea that early Lapita colonists practiced food production and carried domesticated plants and animals during the first push into Remote Oceania. Evidence for the movement of obsidian, adzes, and sometimes pottery (Burley and Dickinson 2001; Green and Kirch 1997; Weisler and Kirch 1996; Weisler and Woodhead 1995) over vast areas during the Lapita Period shows that the full suite of Oceanic domesticates could have become established in Remote Oceania through continued contact with populations in Island Melanesia following the initial colonization of more remote islands.

The importance of food production for early Lapita colonists is far from resolved and further field study will be required to test several alternative propositions. We offer the following testable hypotheses in lieu of a solid statement regarding the importance of food production to early Lapita populations. To start, due to the vagaries of the archaeological record we cannot completely rule out the hypothesis that early Lapita populations transported domesticated plants and animals to more remote islands in Oceania as a package. This remains an alternative hypothesis, although we find no compelling

archaeological, linguistic, or biological evidence in its support at this time. Alternatively, we present two additional hypotheses. The first, favored by Anderson (n.d.a), is that the earliest Lapita colonists were effectively foragers who skimmed the highest ranked marine and terrestrial resources as they dispersed through Vanuatu, New Caledonia, Fiji, and into Western Polynesia (Anderson, n.d.a). The implication of this hypothesis is that early Lapita colonization outran the movement of most food production into Remote Oceania and that domesticates, other than the chicken, were introduced into the Lapita economy during the continuing migration process, probably in a piecemeal fashion, rather than as a package (Anderson n.d.a). The second hypothesis, favored by Kennett, is that the early Lapita economy combined a low-level food production package, as defined by Smith (2001a), of select domesticates: chicken and possibly taro, maritime foraging for shellfish and fish, and the exploitation of the most easily obtainable terrestrial foods (*Canarium* nuts, large birds, eggs, etc.). This mixed production strategy may have been similar to the low-level food production practiced by the Mikea of western Madagascar (Tucker 2001, this volume). In both propositions, foraging for wild foods was the most important strategy initially, but food production increased in importance as people impacted the availability of wild resources, and the abundance of easy prey diminished on each island.

Current archaeological data suggest a pause in colonization activities once Lapita settlements were established in the Fijian, Tongan, and Samoan archipelagos. After this time (~3000 B.P.), settlement pattern data for these island groups suggest: (1) increased number of settlements in coastal locations and other previously unoccupied islands within each archipelago; (2) reductions in settlement mobility (Clark 1999); (3) the expansion of populations into the interiors of larger islands (Clark 1999; Hunt 1987; Sand 1996b); and, (4) intensified agricultural practices, inferred from inland expansion and the development of terracing and irrigation systems. On Vanuatu, the presence of Malakulan

pottery across the landscape suggests the expansion of people into interior locations as late as 1000 years ago. Rapid increases in charcoal frequencies also occur in a core from the Rewa delta on the southeast coast of Viti Levu, Fiji, by about 2300 B.P. (Anderson 2002). This is consistent with the post Lapita phase record from Fiji indicating a depletion of easily gathered natural foods and an increased reliance on agriculture between 2300 and 1900 B.P. (Clark 1999). Inland areas started to be colonized late in the Lapita period, when settlements covered the landscape by 1000 B.P. Group conflict over territory is indicated by the establishment of fortified villages on the landscape by 1200 B.P. (Field 2004). In New Caledonia, intensified agricultural strategies are inferred from new sediment core data suggesting deforestation after about 2500 B.P. (Stevenson 1999; Stevenson and Dodson 1995), and population expansion into interior areas at 2000 B.P. that culminated around 1000 B.P. (Sand 1996b; Galipaud 1996). The first fortifications on the Loyalty Islands at 1800 B.P. are attributed to infilling of the landscape and territoriality (Sand 1996b). This context is more consistent with the despotic variant of IFD and would have stimulated emigration more rapidly.

The evidence for rapid colonization of East Polynesia (~1000 B.P.), if correct, suggests that migrations were initiated from West Polynesia in the context of: (1) increasing population density, (2) decreases in habitat suitability caused by erosion and soil degradation after an initial increase in habitat suitability for agriculture due to forest clearance and terracing; and (3) heightened interference due to territoriality and warfare. Once colonized, subsistence and settlement strategies varied between islands in East Polynesia, but early colonists generally combined the hunting of ecologically naïve flightless birds, large reptiles, and other easy prey, with maritime foraging/fishing and low-level food production. The dominant faunal constituents in early East Polynesian assemblages are near shore reef fish (e.g., 90.4% of assemblage at Tangatatau Rock shelter on Mangaia;

Steadman and Kirch 1990). However, these early faunal assemblages also contain the bones of flightless birds, which were often extirpated within the first few hundred years of occupation of each island. The rapid extinction of twelve species of Moas in New Zealand is well-known (Anderson 1989) though it was probably not as rapid as proposed by Holdaway and Jacomb (2000; see Anderson 2000c). A wide range of other animals was also extirpated (40 species of birds, 1 bat, 3–5 frogs; Anderson 1997, 2002; Worthy 1997) there and elsewhere in the archipelagos of East Polynesia. Heavy intertidal predation pressure, indicated by decreasing shell size through time, is also evident in shellfish assemblages from several islands (Steadman and Kirch 1990). This ubiquitous East Polynesian pattern is evidence for early and rapid extinction, extirpation, or reduction in the largest, or most accessible, animals on each island (Anderson 1981, 1984, 1988; Kirch 1996; Steadman 1989; Steadman and Kirch 1990; Steadman et al. 1994; Weisler 1995).

Intensive agricultural strategies were well developed in West Polynesia prior to the colonization of East Polynesia. The available records indicate that early colonists carried economically valuable plants and animals into East Polynesia. For instance, the early cultural strata at Tangatatau Rock shelter (~1000 B.P.) contain a rich carbonized plant record that includes taro (*Colocasis esculenta*), other root crops (*Cyrtosperma chamissonis*), banana (*Musa*), breadfruit (*Artocarpus altilis*), Tahitian chestnut (*Inocarpus fagiferus*), sugarcane (*Saccharum officinarum*), ti (*Cordyline terminalis*), and the sweet potato (*Ipomoea batatas*) (Hather and Kirch 1991; Kirch et al. 1995; Kirch 1996). Chickens (*Gallus gallus*), pigs (*Sus scrofa*), and dogs (*Canine*) are also evident in East Polynesian records relatively early (Steadman and Kirch 1990). However, an immediate commitment to intensive food production is not evident in the available records. Turning back to the Tangatatau Rock shelter example, the earliest levels contain large concentrations of native land birds and very few domesticated animal bones (chickens or pigs), but the

latter increase through time as the frequency of native landbird species decreases (Steadman and Kirch 1990). The 25 mystery islands of East Polynesia appear to have been abandoned after the collapse of indigenous fauna and before agricultural intensification (Anderson 2001b, Anderson et al. 2002). In several of these instances it appears that only one or two domesticated plants or animals were successfully transported or propagated on these islands.

Some temperate islands, particularly the South Island of New Zealand, were also outside the range of successful cultivation of tropical cultigens. However, on islands that lacked such environmental limitations, or were not abandoned, intensified agricultural strategies appear to develop much more rapidly (~100–200 years) when compared to West Polynesia (~500–1000 years) (Anderson 2002). This parallels evidence for increases in sociopolitical complexity, territoriality, and warfare (Kirch 2000). Evidence for anthropogenic environmental changes of deforestation and erosion appear earlier and were more rapid in East Polynesia (Anderson 2002). This was related, in part, to the small size of these islands, but was also linked to the more developed nature of food production at this late date.

SUMMARY AND DISCUSSION

Hundreds of islands were colonized in Oceania after 35,000 years ago, and each island provided a new set of opportunities and constraints to potential colonists. Basic foraging models (Winterhalder 2001) predict that considerable temporal and spatial variability in colonizing behavior would have existed. Beyond the occupational histories of individual islands, there does appear to be temporal and spatial structure in the process of colonization. Current archaeological data strongly suggest that the migration of people to smaller, more remote islands and archipelagos was episodic and not continuous. Bursts of colonization activity were followed by longer periods of local population growth, environmental infilling, and intensification of subsistence

strategies. Smaller, more remote islands with decreasing resource potential were colonized after periodic delays.

The largest landmasses (New Britain, New Ireland, and Greater Bougainville) in Near Oceania were first colonized by hunter-gatherers between 35,000 and 29,000 B.P. Archaeological evidence for this early time is limited, but suggests that foragers complimented the use of protein-rich intertidal resources with wild plant foods from wetland habitats. This included the exploitation of *Colocasia* taro, a plant species that later became an important Oceanic domesticate (Yen 1995). The periodic use of caves and rock shelters suggests that populations were highly mobile using the landscape extensively. After initial colonization the record suggests a long period of stasis with some evidence for small-scale increases in population after 20,000 years ago and again during the Holocene (~10,000–3500 B.P.; Spriggs 1997). This period saw the infilling of different environmental zones on larger islands and the colonization of smaller adjacent islands in the Bismarck Archipelago and Solomon Islands (e.g., Manus; Spriggs 1997). As populations increased, habitat suitability would have decreased due to resource depletion or interference, stimulating intensification or migration.

The presence of non-native species of trees and animals (e.g., chestnut and marsupial possum) in late Pleistocene deposits in Near Oceania (~13,000 years ago) suggests that people were actively manipulating the landscape and possibly compensating for exploitation-induced depression in the availability of naturally occurring foods (Anderson 2001b). Intensified subsistence strategies are evident at interior locations where possum were aggressively targeted (Marshall and Allen 1991; White et al. 1991), in Holocene shellfish assemblages suggesting increases in diet breadth, and perhaps in the development of arboriculture by about 4000 B.P. Population increases and the intensification of subsistence strategies occurred in the context of global sea level rise after 18,000 B.P. that reduced the size of islands in the Bismarcks and

inundated portions of Greater Bougainville to form the modern-day distribution of islands in the Solomons (Fairbanks 1989; Thiel 1987). Coastal wetlands would have become increasingly productive with the stabilization of sea level after 7000 years ago and may have contributed to intensified use of maritime resources after this time.

Despite several decades of work in Remote Oceania, there is no evidence for occupation east of the Solomon Islands prior to 3300 B.P. (Anderson et al. 2001a). The ideal free distribution model predicts that these more remote islands would have been colonized only when average subsistence returns there were equal to those in the Bismarck Archipelago or the Solomon Islands. Delayed colonization of these remote islands (~30,000 years) suggests that (1) population in the Bismarcks and Solomon Islands were not experiencing sharp decreases in habitat suitability, but perhaps the opposite, an Allee effect; (2) initial suitability of these remote islands was low; or (3) the dispersal of populations to these islands was restricted because of environmental, technological, or social barriers (e.g., territoriality). A combination of these factors likely contributed to delayed colonization of more remote islands in the Pacific.

Other factors may have impeded colonization as well. Clark and Kelly (1993) have argued that endemic malaria, common in the region today, caused high infant mortality and kept early populations in Near Oceania relatively low. It is also probable that resource availability in New Caledonia and Vanuatu, as well as other remote islands, was comparatively low due to their limited terrestrial plant and animal diversity (Anderson 2001a; Spriggs 1997). In addition, these islands are all south of the equator and are subject to greater seasonal differences in temperature and rainfall (Spriggs 1997). In the absence of agriculture and storage, seasonal resource shortfalls—likely to have been more pronounced during Pleistocene glacial conditions—would have constrained the viability of colonization. Current data suggest that these islands were unoccupied until the late Holocene so

impediments due to resistance of earlier settlers were certainly not a problem, but environmental and technological barriers may have inhibited colonization. For example, the water gaps between islands were greater (over 300 km) and may have required more specialized maritime technology.

The appearance of Lapita settlements in the Bismarck Archipelago was a major threshold in Oceanic prehistory that represents either an outgrowth of indigenous developments (Allen and White 1989; Gosden 1992), an intrusion of Austronesian peoples from Southeast Asia (Bellwood 2001; Spriggs 1997), or a combination of the two (Green 1991). Lapita settlements were strategically positioned near or over, by means of stilthouses, coastal lagoons that were often on small islets adjacent to larger islands occupied by indigenous, non-Lapita, hunter-horticulturalists. The placement of settlements on smaller islands suggests that other island habitats were full or that Lapita peoples selected locations to avoid hostilities or endemic malaria that likely plagued indigenous communities in Near Oceania at the time (Clark and Kelly 1993). The frequency and size of Lapita settlements suggest that populations increased more rapidly relative to contemporaneous hunter-horticultural communities on adjacent islands. The economic engine for increased population growth probably consisted of intensive maritime foraging coupled with low-level food production that intensified through the interval. It is also possible that rapid population increase was partially related to reduced susceptibility of Austronesian populations to endemic malaria (Kelly 1999). Regardless, population increase in Lapita communities ultimately outpaced indigenous populations which were swamped or replaced.

Lapita migrants in Near Oceania entered landscapes that were depleted of larger game animals and other easy prey (Allen 1996). The productivity of intertidal resources like shellfish was also reduced, at least in some areas, because of sustained exploitation for thousands of years (Spriggs 1997). Lapita faunal assemblages indicate a clear maritime focus and improvements in seafaring with fishing technologies available

as early as 3300 B.P. Reductions in habitat suitability due to resource depression and interference were probably exacerbated by interference from hostile indigenous populations. It was in this context that, following a lag of several hundred years, voyaging and colonization activities increased and the more remote parts of Oceania—New Caledonia, Vanuatu, Fiji, Tonga and Samoa—were colonized between 3000 and 2800 B.P. (Anderson 2001a).

As the vigor of eastward colonization began to wane 2700 years ago, and Lapita pottery started dropping out of the archaeological record, there is increased evidence for reduced settlement mobility and intensified food production in Fiji, New Caledonia, Tonga, and Samoa (Clark 1999; Sand 1996b). Intensive food production in Remote Oceania is signaled by large-scale forest clearance, intensive erosion, and the movement of soils from hillsides to valley bottoms (Anderson 2002). This culminated in the settlement of interior locations and the terracing of hillsides to contain erosion and maximize the amount of cultivated land. Territoriality and social circumscription are suggested by the appearance of fortified settlements in lowland and upland settings (e.g., Best 1993; Field 2004), contributing to decreases in habitat suitability that would have promoted emigration. The emergence of more intensive strategies varies between islands, but they were well established throughout West Polynesia by 1000 years ago. Several forms of intensive food production were evident by this time, including terracing, pond-field cultivation of taro, and irrigation agricultural systems (Clark 1999).

If our current estimates for the colonization of East Polynesia are correct, then the population increases, environmental infilling, and agricultural intensification evident in West Polynesia occurred during a pause in eastward colonization activity that lasted for more than 1500 years (Anderson 2002). Many of the islands in East Polynesia were colonized rapidly after 1000 years ago and New Zealand was colonized as late as 800 B.P. Except for New Zealand, all of the islands in East Polynesia are relatively small and

are not complex ecologically. The biological diversity on these islands is low, the productivity of marine habitats declines from west to east, and seasonal variations in temperature and rainfall become accentuated particularly on subtropical islands. Rapid extinctions of the largest landbirds and reptiles, evident archaeologically (Anderson 1989; Steadman and Kirch 1990), reduced the biological diversity of these islands further still.

Human ability to discover and colonize islands was dependent on factors of access, such as island size and remoteness, prevailing climatic and environmental conditions in relation to maritime activities, and the availability of seafaring technology and knowledge (Anderson 2000a; Erlandson 2001; Irwin 1992; Spriggs 1997). However, the data from Oceania are generally consistent with the predictions of the IFD model: the long interval between the initial colonization of Near Oceania (35,000 B.P.) and Remote Oceania (3300 B.P.) consistent with the IFD curve for foragers living on large islands; the more rapid succession of colonization episodes in Remote Oceania after the establishment of Lapita populations in West Polynesia more consistent with IFD curves for food producers on small islands. The 200–400 year pause in colonizing vigor after the first arrival of Lapita people in Near Oceania and the 1500 year pause in West Polynesia prior to the colonization of East Polynesia, if upheld archaeologically, is also consistent with the infilling of populations and the intensification of subsistence strategies in Near Oceania and West Polynesia respectively.

Thus, there appears to be a close match between the scale of this HBE model and the available archaeological data (c.f. Smith, this volume). IFD predictions are ones of central tendency, the probabilistic equilibrium result of a large number of individual decisions made over a time interval that allows for several rounds of adjustment in habitat choice. Likewise, the overall history of colonization in Oceania, as recorded in the archaeological record, smoothes highly localized decisions over sufficiently long periods of

time and enough repetitions of migration events that patterning becomes visible at a scale concomitant to that of the model.

Nevertheless, the episodic nature of colonization now evident in the archaeological record could be the result of other historical processes. For instance, colonization episodes could have been triggered by periodic advances in seafaring technology, both of boats and navigational and other sailing skills (Anderson 2000a). Direct archaeological evidence for boats is uncommon and makes this hypothesis difficult to test. The neotraditional assumption is that celestial navigation techniques were well developed and that large double-hulled canoes existed prior to the colonization of Remote Oceania (Irwin 1992). Yet, the late Holocene appearance of Lapita assemblages coincides with a sixfold increase in voyaging range into the prevailing wind and likely signals the first arrival of the sail and possibly the outrigger (Anderson, 2000a, 2001c, n.d.a). Linguistic data, furthermore, suggest that the large double-hulled canoes were a relatively late development, certainly after the colonization of Fiji and West Polynesia (Blust 1997; Anderson n.d.a). The colonization of extremely remote islands in East Polynesia was probably contingent on the development of the double-hulled canoe (Anderson 2000a, 2001c). Developments in maritime technology, therefore, were one important component in the episodic nature of colonization, particularly for the discovery and assessment of remote islands. Given the probable nature of early sailing technology, particularly the likely absence of an upwind capacity (Anderson 2000a, 2001c), the larger numbers of voyages may have occurred during periods of wind reversal related to millennial scale changes in climatic and associated oceanographic conditions (Anderson n.d.b). Long-term climatic change may turn out to be another key element in explaining the episodic nature of the colonization of Oceanic islands.

An important assumption of the IFD model employed here is that the costs of relocating were small enough to be ignored. Setting sail across

the Pacific without prior knowledge of habitable islands would have been risky and potentially costly, but it might not have been perceived in that light. In any event, we have assumed, for the sake of simplicity, that the locations of surrounding, uninhabited islands were known to emigrants, their position and relevant agro-ecological features having been scouted prior to colonization. To this extent, the decision to disperse would have been an informed one, and of relatively low risk and cost in transportation when considered relative to the lifetime scale of its consequences. In some cases this assumption may be unrealistic because of the distances traveled to Fiji, Easter Island, and Hawaii and the ability of early island explorers to return to their home islands given prevailing winds and limitations imposed by maritime technologies (Anderson 2003b, n.d.a).

Given these limitations we suspect that the colonization of islands involved a dispersal phase and a migratory phase (Anderson, n.d.a), the former being the outward, one-way initial occupation of islands, the latter a two-way process involving the movement of people back and forth between island groups along with food and goods. Dispersal would have been an exploratory phase when the resource potential of islands was assessed given available subsistence practices and technologies. This phase would have been riskier, and therefore more costly, than the migratory phase when more information was available regarding target islands. Therefore, we envision the colonization of islands as a process rather than an event. Regardless, population-dependent decreases in island suitability would likely stimulate dispersal and migration in much the same way, but the costs of dispersal would have been considerably higher relative to the follow-up migration process and would have contributed to the long pauses between colonizing episodes.

The distinction between dispersal and migration phases is important when considering the role that food production played in the initial colonization of Remote Oceania by Lapita peoples. We have proposed alternative hypothe-

ses in response to the traditional assumption that food production was one of the primary contextual changes that stimulated the colonization of Remote Oceania (Kirch 2000; Spriggs 1997), a hypothesis that is currently not well supported by the available archaeological data. One proposition is that early Lapita peoples were mainly foragers who skimmed the highest-ranked resources from pristine island environments in Remote Oceania. The second proposition is that these people combined low-level food production of taro and chicken with foraging for wild food, both terrestrial and marine. Regardless, it is clear that food production was not essential for the initial dispersal of people into Remote Oceania in a strict economic sense. The known early Lapita assemblages in Near and Remote Oceania are dominated by marine resources and contain few, if any, domesticates. If early Lapita people were foragers (Hypothesis #1) then the decision to disperse was not stimulated by the perceived advantages of food production on smaller, more remote islands that would not have sustained foraging economies, increased productivity, and decreased subsistence risk. This would suggest that early Lapita peoples sailed away from low-level food production and that they only brought in domesticated plants and animals as the suitability of island habitats in Remote Oceania decreased with faunal collapse, one form of resource depression.

Alternatively, the combination of low-level food production and intensive maritime foraging in Near Oceania may have contributed to decreases in island habitat suitability during the 200–400 year period that separates the first appearance of Lapita peoples and their dispersal into Remote Oceania, in combination with long-term decreases in habitat suitability associated with a sustained, long-term occupation by hunter-gatherers. This mixed subsistence strategy would also have changed the perception of the overall resource potential of smaller, more remote islands while decreasing subsistence risk. Therefore, domesticates may have played a significant role in the decision to disperse even

if the role of food production was minor initially, due to the local availability of wild resources. In the absence of competing populations, the earliest settlement on these islands would be expected in optimal locations for collecting marine and terrestrial resources and low-level food production. Less optimal locations in the interior are expected to develop later. Deforestation, sediment loading in valley bottoms, and terracing could have created an Allee effect where larger populations were possibly supported prior to environmental degradation. More despotic/territorial behavior would be expected with habitat infilling as would the intensification of agricultural strategies. Both would have contributed to more rapid emigration. Evaluation of this hypothesis is dependent upon larger-scale excavations in Early Lapita sites in Near and Remote Oceania coupled with new technology for detecting domesticated plants in environments unfavorable for the preservation of organic material, such as starch grain and phytolith analysis.

Food production appears to have been well developed before the colonization of East Polynesia and certainly contributed to relatively rapid decreases in habitat suitability that played an important role in the decision to emigrate. The availability of domesticated plants and animals to augment the depauperate environments of remote islands probably influenced the decision to emigrate. However, in a similar fashion to the Lapita colonization of West Polynesia, the initial generations of colonists were subsidized by naïve and easily captured game. Successful and persistent settlement of these ecologically impoverished islands was often dependent upon a rapid increase in agricultural production. Pollen and charcoal records from different islands indicate that extensive forest clearing and burning started within a century of colonization (Anderson 2002). Intensive agricultural production involving terracing, irrigation, and pond-field cultivation developed rapidly suggesting that domesticated plants and animals, along with extensive agrarian knowledge, were carried by early colonists. Direct archaeological evidence

for this is also available (Kirch 1996). The most productive island habitats were selected, and early colonists combined the hunting of ecologically naïve landbirds and reptiles with continued maritime foraging and agriculture. The rapid extinction of larger fauna caused by over-exploitation was compensated by increased food production, which intensified in parallel with increased population density. In some cases, faunal collapse on islands with little agricultural potential resulted in abandonment (e.g., Pitcairn, Norfolk and 23 others; Anderson 2001b). On other islands rapid extinction resulted in agricultural intensification, rapid population growth, the formation of large villages, territoriality, and more centralized political systems founded upon hereditary leadership (Kirch 2000).

CONCLUSION

The proposed Ideal Free Distribution model provides a framework that considers the dynamic character of island habitat suitability along with density-dependent and density-independent variables influencing migratory behavior. The archaeological data from Near Oceania is consistent with the IFD curves for hunter-gathers living on large islands. Evidence for the more rapid colonization of Remote Oceania is consistent with IFD curves for food producers living on small islands. The model also accounts for the episodic nature of island colonization. The initial generations of colonists in Near and Remote Oceania were subsidized by relatively dense and easily captured populations of naïve game. This phase lasted several generations, the bounty and persistence of this windfall a function of island size. Declines in wild resources appear to have been offset by intensified foraging and the translocation of wild animals (Near Oceania) or efforts to replace these resources with expanding food production (Remote Oceania). In Remote Oceania the transition from dependence on an ephemeral local bounty of foraged resources to a stable and fairly productive regime of cultivation was the point of greatest risk for successful colonization,

while it is clear from the abandonment of several islands after faunal collapse that it was not always successful (Anderson 2003b). The population that made it through this period of vulnerability, then experienced an Allee effect of increasing economies of scale in food production. Local habitat suitability grew as an effective system of agro-ecological production was developed. This phase was one in which population was locally tethered; it lasted for a relatively long interval before overpopulation, circumscription, and possibly environmental degradation began to reduce suitability, leading to a new round of emigration if suitable, uninhabited islands were available. The length of each phase in this cycle was a function of island size, which would mean that, once a colonization episode was initiated, small islands in East Polynesia would have been colonized rapidly and relatively continuously. The rapid development of social stratification in East Polynesia after colonization also accelerated the tendency for emigration.

Our formulation of this model is based on fundamental HBE principles, the IFD model in particular, and our interpretations of the available archaeological data in Oceania. The model predicts that colonization of Oceania would have been episodic and not continuous. New radiocarbon chronologies throughout Oceania should continue to confirm the episodic nature of colonization starting 35,000 years ago. The model also predicts that a relationship exists between population density and habitat suitability. Therefore, substantial population growth and reductions in habitat suitability should be clearly evident in the palaeoenvironmental and archaeological records in source archipelagos prior to the next episode of emigration. More rapid reductions in habitat suitability are expected with intensified food production strategies in that emigration would be expected prior to large-scale agricultural intensification. The most intensive food-producing strategies such as pondfields or terracing should be evident on

islands in East Polynesia late in prehistory when options for emigration were limited. We argue that this scenario is plausible, and testable. However, we note that others might be devised within the framework of the IFD, perhaps giving greater attention to social stratification and resource inequalities, and thus to a despotic variant of the IFD.

Our use of the IFD model also is qualitative and general, as is our assessment of its fit to the available archaeological data. A more robust application would develop out of independent quantitative information on available habitats, including measurement of their ranking (quality) and the response of their suitability to increasing human populations. The latter requires careful determination of the shape of the suitability/density curve. The information on migration and settlement required to test this model would include the sequence and timing of intra-island settlement of habitats, and inter-island migration, both relative to the population history and its density in particular locales. It also would require observations on the socioeconomic conditions pertinent to “free” or “despotic” regimes of resource competition. It is encouraging that this type of data is archaeologically accessible, and will eventually become available in sufficient detail to evaluate the explanatory potential of the IFD in this setting in a more quantitatively rigorous fashion.

NOTES

1. The islands of Micronesia are not considered in this paper, but the ideas explored here could easily be extended to that vast region.
2. All Pleistocene and early Holocene dates are reported in radiocarbon years before present and dates in the late Holocene are calibrated years before present.
3. This pattern could also be caused by differences in the amount of archaeological fieldwork completed in each region, but sustained work in both Near and Remote Oceania for the last 40 years would suggest that this is not the case.