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Responses to a Drought in the Interior Lowlands of Papua New Guinea: A Comparison of Bedamuni and Kubo-Konai

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The ways that people experience, respond to and pattern recovery from major climatic aberrations must be understood within the context of existing socioeconomic arrangements and the ethos that informs these. This paper describes immediate and longer term impacts of a major drought on two populations—Bedamuni and Kubo-Konai—in the interior lowlands of Papua New Guinea. Though they occupy similar environments, are culturally related and reliant on similar technology and resources, these two populations differ in density, intensity of land use, and social complexity. The drought of 1997 affected one of the populations much more severely than the other. A comparison of effects on subsistence regimes, mobility and social life in the two areas suggests that these were mediated by understandings people held of relationships with both the environment and other people. Bedamuni pattern their lives around an expectation of favorable returns on effort, emphasising security of tenure to protect those returns. Kubo-Konai, in contrast, pattern their lives around an expectation that availability of resources will be often in flux, and emphasise means of ensuring security of supply. These understandings are reflected, respectively, in risk-prone and risk-averse strategies of subsistence and sociality which directly influence vulnerability and responses to disruptive events.

KEY WORDS: Papua New Guinea; drought; food insecurity; coping strategies; risk sensitivity; tenure systems; mobility.

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INTRODUCTION

In this article we compare effects of a major drought on, and responses to and recovery from that drought by, two small populations (Bedamuni and Kubo-Konai) from a region of the interior lowlands of the Western Province, Papua New Guinea, where rainfall is usually very high and without marked seasonality. The comparison, informed by our studies of both populations prior to the drought, reveals subtle effects of altitude, subsistence mode and prevailing social forms on people's immediate and longer-term responses to disruptive events. Our particular concern is with the intersection of social and ecological factors in constraining those responses.

From the outset we note that, because of the relative isolation of the area, coping mechanisms that entail reallocation of resources (e.g., income from cash crops) to the purchase of food or relocation to towns were not available options for the people discussed (cf., Allen and Bourke, 1997; Corbett, 1988). Rather, we show that the usual risk-prone character of Bedamuni subsistence decisions, in contrast to the risk-averse subsistence behavior of Kubo-Konai, underlay differences in the ways in which these populations experienced and coped with the drought. With specific reference to Bedamuni and Kubo-Konai we argue that risk-prone and risk-averse strategies, which respectively emphasise security of tenure and security of supply, were themselves crucially informed by sociality and ethos and, hence, that the latter played a major role in shaping what happened during and immediately after the drought. Here, then, we are aligned with Watts' (1983, pp. 256–259) understandings that environmental crises may throw ''into sharp relief the structure of social systems'' and that vulnerability and response to drought are likely to reflect capacities inherent in those systems more than the intensity of the drought itself.

The literature on vulnerability is large (e.g., Hewitt, 1983; de Garine and Harrison, 1988; Huss-Ashmore and Katz, 1990; Watts and Bohle 1993). That literature often acknowledges, but less often demonstrates, the importance of pre-existing local and social strategies for coping with crisis. Rather, as Hewitt (1997, pp. 183–184) stressed, it often treats crises as being the result of extrinsic impacts which require extrinsic solutions. This bias is understandable given both the loss of life that may be associated with major crises and the structure and competing interests of aid agencies (cf., Horowitz, 1990; Waddell, 1983). But it is also a consequence of the fact that seriously affected populations have often had long histories of engagement in global economies and structures

and their responses to crises reflect that engagement. In these circumstances and, particularly in the absence of long-term prior research, the role of customary expressions of sociality and ethos may be masked. Our understanding of the Bedamuni and Kubo-Konai cases, though primarily descriptive, foregrounds the place of intrinsic factors in an understanding of vulnerability.

BACKGROUND TO THE DROUGHT

Through 1997, drought, frost and fires through much of Papua New Guinea were associated with a major El Niño Southern Oscillation (ENSO) event (Allen, 1998; Bourke, 2000; Monsef *et al.*, 1998). ENSO events entail intense, extensive and prolonged warming of the eastern tropical Pacific which occurs every eight to 13 years, and are associated with major meteorological anomalies. The outcome in 1997, when El Niño conditions as reflected by the Southern Oscillation Index were the most extreme recorded since the late 1950s, was a significant decline in cloud cover and rainfall over Papua New Guinea (Allen and Bourke, 1997). The drought that ensued was judged to be one of the most severe to affect the country in the previous 100 years. In some places it was underway in April and, by July, was widespread.

Effects of the drought and associated frosts and fires on life support systems were variable. Altitude, usual climate regimes and commitment to particular staple foods influenced this variation. Thus, food shortages were reported to be critical in high altitude parts of Papua New Guinea where frosts destroyed the staple crop of sweet potato. In middle and low altitude areas garden production was greatly reduced and access to sago flour was jeopardized because either starch content in the palms was reduced, water was unavailable for processing, or fires had damaged stands of palms. Allen and Bourke (1997) reported that, by October, villagers were selling assets and spending cash reserves to purchase food and in parts of the country large scale outmigration had occurred. They noted, however, that outmigration was a traditional response to famine conditions. By December 1997 it was estimated that about 1.2 million people were ''suffering a severe, and to some a life threatening, food shortage'' and that 250,000 people were exposed to critical or severe water shortages (Allen *et al.*, 1998).

At the time of the first official drought assessment, in September and October 1997, Bedamuni and Kubo-Konai were judged to be among the most severely affected populations in the country. From November 1997 to January 1998 they received food aid.

BACKGROUND TO THE PEOPLE

Bedamuni and Kubo are technologically, linguistically and culturally related, occupy similar environments, and have access to essentially the same resources (Dwyer *et al.*, 1993; Kelly, 1993; Knauft, 1985a; Shaw, 1986). They represent extremes of population density, agricultural intensity and social complexity within the northwest section of the Strickland-Bosavi region (Fig. 1; Minnegal and Dwyer, 1998). The former are a population of approximately 5000 people, most of whom live at altitudes between 150 and 300 m in an area of dissected volcanic foothills. Average population density in the 1990's was about 7 people/km^2 and, within central areas, about 75% of vegetation is anthropogenic. The latter are a population of approximately 500 people, most of whom live at altitudes between 80 and 150 m in an area of swamp-forest and foothills. Average population density is less than 0.5 people/km^2 and about 1% of vegetation is anthropogenic. Our previous work has been based at Ga:misi village (lat. 6°17′S, 142°28′E) in Bedamuni territory and Gwaimasi village (lat. 5°54′S, 142°06′E) in Kubo territory. Three other Kubo communities, Sosoibi, Dimobi, and Mome Hafi, and one neighboring Konai community, Soeya Hafi, are also relevant to this article; together with Gwaimasi, they are referred to as Kubo-Konai (or Strickland River) communities. Ga:misi in Bedamuni territory and the collective of Strickland River communities each includes about 100 residents.

The subsistence base of Bedamuni has a major emphasis on gardening with use of sago resources and the role of hunting secondary; thus, these people are primarily dependent on delayed-return resources. In contrast, Kubo-Konai communities near the Strickland River place roughly equal emphasis on gardening, sago production, and hunting-fishing; immediate-return resources are far more important here than among Bedamuni. Soil fertility and sustainability are lower, and drainage less adequate, near the Strickland River than in Bedamuni territory (Bellamy, 1986) and these characteristics influence differences in systems of plant food production. Thus, among Bedamuni, the agricultural system has two components; a cycle of about 20 years for bananas that are grown in unfenced gardens and a cycle of up to 10 years for tubers (yams and taro) that are grown in fenced gardens on land that has previously been planted with bananas (cf., Allen *et al.*, 1993). For the most part the Strickland River communities operate on a single fallow cycle; they place far less emphasis on tubers and seldom fence any gardens. The Bedamuni system, particularly in its emphasis upon seasonal planting of *Dioscorea* yams, imposes a synchronicity on the scheduling of tasks that is not seen among Kubo and Konai. Other expressions of the difference in intensity of plant food production

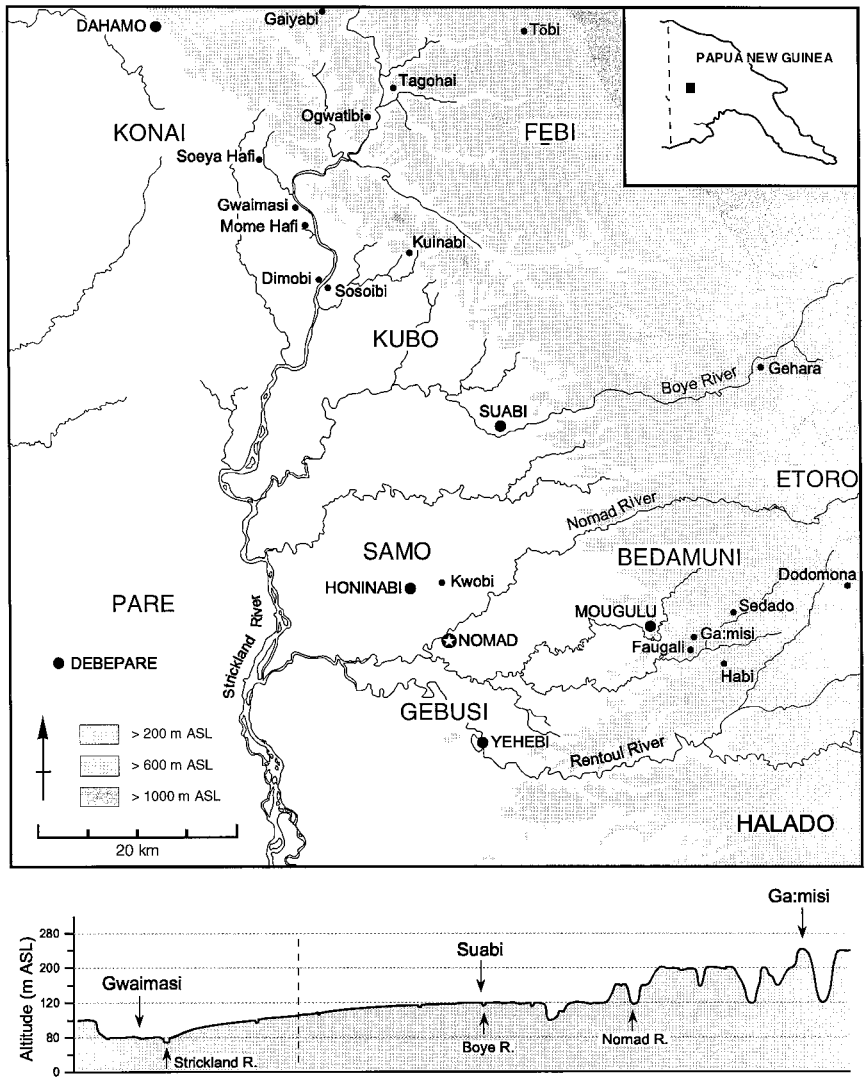

Fig. 1. Map of study area and altitudinal cross-section from Gwaimasi, via Suabi, to Ga:misi. Locations to which food aid was delivered in late 1997 and early 1998 are shown as larger solid circles. The diagram is based on the Karoma and Nomad maps of the PNG 1:100,000 Topographic Survey (Sheets 7385 and 7386, edition 1, Series T601, printed 1979). The vertical dashed line on the altitudinal transect marks the junction of the two maps; here there is a mismatch between altitudes assigned to contour lines. The diagram assumes that the northern Karoma map is more likely to be accurate but, in fact, from about Suabi to Ga:misi on the cross-section altitudes could be up to 40 m higher than indicated.

are evidenced by higher planting densities of bananas, more maintenance and higher yields at Bedamuni gardens than at Kubo-Konai gardens. Relative to the latter people, Bedamuni also use more intensive procedures and extract more flour per unit volume of pith when processing sago.

These ecological differences have social correlates. The emphasis among Kubo-Konai on immediate-return resources, for example, is reflected in an ethos of generalized reciprocity, the 'immediacy' and 'equivalence' that characterizes exchange transactions, and reliance on ''exit'' as a means of resolving disputes (Dwyer and Minnegal, 1998). It is reflected also in the latitude individuals have with respect to places where they live, the understanding that they are free to use resources in these places, and the fact that social identity and association with land are constructed primarily from the actions of individuals as they satisfy needs and wants rather than from conventions of genealogical and historical ties to other people and to land (Minnegal and Dwyer, 1999). Indeed, we have argued elsewhere that relationships between Kubo-Konai communities, established and maintained through frequent visits and residential shifts, ''held the promise, for individuals or families, of access to resources at a temporal scale that might facilitate response to future, but unpredictable, social or ecological contingencies'' (Minnegal and Dwyer, in press). On all these counts Bedamuni differ from Kubo-Konai; their emphasis on delayed-return resources is accompanied by more particularized and restricted patterns of sharing, ''delay'' and ''non-equivalence'' in many exchange transactions, ''negotiation'' as a preferred means of dispute resolution, more restricted opportunities with respect to places where they live, and the importance of genealogical and historical ties in the construction of social identity and relationships with land (Dwyer and Minnegal, 1999; Minnegal and Dwyer, 1998). In effect, commitment to place is considerably greater among Bedamuni than among Kubo-Konai.

On the basis of these differences, and before the drought of 1997, we wrote of the ''potential vulnerability'' of the Bedamuni system relative to that of Kubo-Konai (Minnegal and Dwyer, 1998, p. 395). We did not, however, predict ways in which this might be either triggered or expressed. The drought of 1997 provided a potential trigger. Our subsequent observations, reported here, make possible an assessment of the ways in which differing modes of sociality and ethos influenced responses to that event.

METHODS

We were not present in Papua New Guinea during the drought. Our interpretations of events through that time are based on information gath-

ered during fieldwork among both populations in December 1998 and January 1999, one year after the drought broke, supplemented by reports from drought assessment teams and other outsiders (missionaries and health workers) who resided in or visited the areas at various times during and after the drought. Much of the information included in this paper was elicited from local residents, and is necessarily qualitative. In assessing that information, we stress that, first, in both populations adults are very knowledgeable as regards matters of subsistence, second, they seldom express knowledge of past events in quantitative terms and, thirdly, Bedamuni are more inclined to exegesis than Kubo-Konai (Minnegal and Dwyer, 1998, pp. 389–391). Our interpretations of these diverse strands of information are situated within the frame of earlier studies with both populations. Those studies commenced in 1986 among Kubo-Konai and 1995 among Bedamuni (Dwyer and Minnegal, 1991, 1992, 1993, 1994, 1998, 1999; Dwyer, 1993; Minnegal, 1997; Minnegal and Dwyer, 1997, 1998, in press; see also Sørum 1980, 1982, 1984, n.d., and Beek, 1987, on Bedamuni). Some difficulties of comparison arise because, first, our 1998–99 field research was brief and, second, occurred 2 years after earlier work among Bedamuni but 3 years after earlier work among Kubo-Konai.

Rainfall patterns through Papua New Guinea vary greatly both locally and regionally (McAlpine *et al.*, 1975). This variation was apparent through the course of the drought in 1997 and early 1998. There are no long-term rainfall records available that can be safely extrapolated to the areas that are focal to this article. In the next section we draw on records from a mission station located half-way between the two communities at which we lived and on others, including our own, from elsewhere in the Strickland-Bosavi region. We also comment on ways in which Bedamuni and Kubo-Konai spoke of effects of the drought on local environments.

Again, there are no reliable base-line statistics concerning health of Bedamuni and Kubo-Konai. Nor are there reliable quantitative data concerning the impact of drought on health from elsewhere in Papua New Guinea (Bourke, 2000). In this article, comments on health and mortality draw on statements from local health workers, outsiders who assessed available food supply and needs during the course of the drought, residents of local communities, and our own impressions.

Our data include more quantitative information with respect to effects on gardening practices, sago production, pig husbandry, hunting, demography, mobility, and social life. It is these themes that are emphasized in what follows. Details of methods used to obtain the quantitative data that appear below are provided in our earlier articles. Details of gardening work during and following the drought incorporate information provided by those who did the work together with our assessment, based on observations

in December 1998 and January 1999, of the times particular gardens had been initiated.

RAINFALL AND ENVIRONMENTAL EFFECTS

Annual rainfall in the northern section of the Strickland-Bosavi region is in the range 5000–7000 mm.[2] Records of monthly rainfall from July 1995 to December 1998 at Suabi Mission Station in Kubo territory are shown on Fig. 2a.[3] The trace for 1997 shows a consistent decrease in monthly totals from January to October and a return to levels within the ''normal'' range after that time. The total for 1997 (i.e., 3858 mm) was 56% of the average for 1996 and 1998. The total from May to November 1997 was 30% of the average for the same months in the other 2 years and, in the three critically dry months, August to October 1997, only 11% of the expected value based on records for 1995, 1996, and 1998.

Total rainfall at Suabi in 1997 appears high relative to the serious impact on food production systems that occurred in the region (cf., Salafsky, 1994, on rainfall and drought in West Kalimantan). It is likely, however, that shifts in the pattern of rainfall have more significance for plant production systems than annual or even monthly totals. The number of days per month that are without rain and, particularly, runs of days without rain will be positively associated with absence of cloud cover and higher temperatures and levels of evapo-transpiration (cf., Jipp *et al.*, 1998; Still *et al.*, 1999). Figure 2b records days per month without rain at Suabi from July 1995 to

[2]Knauft (1985b, p. 16), Beek (1987, p. 216) and Shaw (1990, p. 40) reported annual rainfall of between 2950–5400 mm on the basis of records taken and held at Nomad Government Station; McAlpine *et al.* (1975) reported an average of 4272 mm from the same location. Shaw commented that records from Nomad were ''riddled with blanks'' and added that annual totals were ''considerably lower than my own unofficial records.'' He suggested a yearly average, from Kwobi in Samo territory where he was based for lengthy periods across 12 years, in excess of 5080 mm. Records for 12-month periods from five other locations in this region suggest that annual totals in the range of 5000 to 7000 mm are usual (Dwyer, 1990, p. 23–24; Ernst, 1984, p. 23; Kelly, 1977, p. 32; Minnegal and Dwyer, 1995; Sørum, 1980, p. 273). Comparison of rainfall records from runs of 144 days at Gwaimasi (August 1995 to January 1996) and 34 days at Ga:misi (December 1996 to January 1997) with records for the same days at Suabi reveal similar patterns and, for the longer run of days, similar totals. The impression is that the three locations experience similar rainfall regimes.

[3]Rainfall records at Suabi were recorded by Tom Covington or, in his absence, his agent. 'N/r' (no record) was recorded against nine days from July to December 1995 and 14, 8, and 43 days, respectively, in 1996, 1997, and 1998. Rainfall recorded on the day following an 'n/r' record or a sequence of 'n/r' records is cumulative but, in fact, some days recorded as 'n/r' may have been days without rain. In the unlikely event that all such records were days without rain the only substantive modification to Fig. 2b would be to increase the number of days without rain to 11 or 12 in the months March to May 1998.

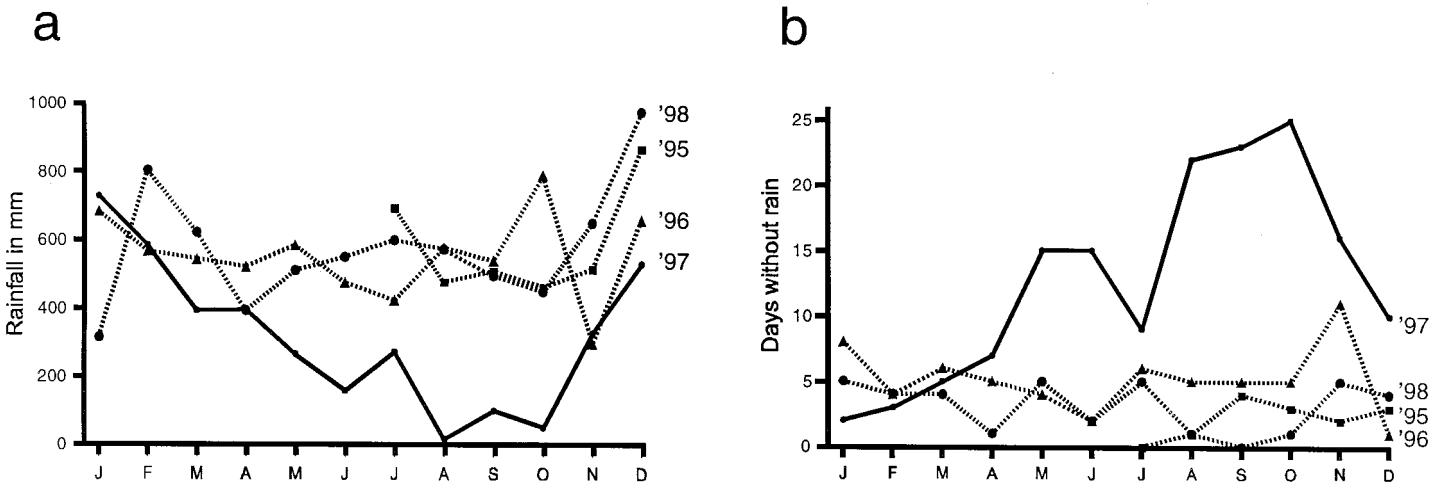

Fig. 2. (a) Total rainfall and (b) days without rain per month at Suabi, July 1995 to December 1998.

December 1998 and reveals a much higher than normal incidence of dry days from April to November 1997. Further, during this period, dry days were likely to occur in succession; the longest run of dry days in each month was, on average, 8.9 ± 4.7 days from April to November 1997 ($n = 8$) and only 1.67 ± 0.9 days for the remaining months in the sample ($n = 34$). Records taken at Gwaimasi in 1986, showed that in the absence of rain over periods of four or more days, maximum temperatures increased from a daily average of 30–32°C to 35–36°C. Where these higher temperatures are sustained for lengthy periods, evaporative water loss will be high with potentially deleterious effects on plant production in general and garden crops in particular.

Both Bedamuni and Kubo-Konai spoke of the drought as being a time of ''strong sun'' (Bedamuni, *eso bagade*; Kubo *aso kaudi*). Bedamuni emphasized the defoliation of forest, the drying of garden crops, and local fires that had burned areas of forest. Their particular concern was with the deleterious impact of drought on food production systems; they did not report earlier events of comparable magnitude. In contrast, Kubo-Konai emphasized reduced visibility as a consequence of smoke from major fires beyond their own territory; they reported that some people experienced breathing difficulties and that, at times, they could not see from one side of the river to the other. Forest trees here had not lost their leaves, though it was known that this had happened in areas to the south-east. They did not volunteer a concern with the deterioration of food production systems (though they enthusiastically reported receiving ''supply'' food) and, only at asking, reported two minor fires that had got out of control. The three oldest surviving Kubo men recalled an earlier occasion—apparently, the El Niño related drought of 1941–42—when, they asserted, the effect on local streams had been greater than in 1997.

Bedamuni reported that river levels fell progressively through 1997. The upper reaches of small and large streams dried; the lower reaches were reduced to pools of often stagnant water and the people, whose villages are usually on ridge tops, were obliged to travel further for drinking water. Some families relocated down-slope to the rivers (cf., Beek 1987, p. 10). Similar, but less pronounced, effects on streams and drinking water sources were reported by Kubo-Konai. The Strickland River was most dramatically affected, with sediment loads greatly reduced; the river turned ''green,'' we were told, in contrast to its usual brown. Flow was greatly reduced in larger tributaries; by late 1997 even those that drained swamps were little more than a string of connected pools. When substantial rains fell again, at the end of the drought, accumulated leaf litter was washed into these streams; the rotting vegetation released a ''bad'' smell and many fish died. Bedamuni did not report a comparable effect, presumably because, in

the steeper terrain of their territory, leaf litter and debris were rapidly washed away.[4]

PLANT FOODS AND GARDENING PATTERNS

By late September 1997 production from Bedamuni gardens was reported to be very poor and expected to cease entirely (Wissink, 1997). Banana plants that had set bunches were producing only two or three hands. The fruit were small and dry, had often split open and were, people said, ''without taste for us to eat.'' Taro and yams, most of which are planted seasonally, would have been harvested by this month and sweet potato were either dry or badly infested with weevils.

From September to the end of 1997, we were told, very little food was harvested from gardens and wild plant foods were difficult to obtain. Gardens were brown and defoliated. All garden and tree crops had ''finished''; none yielded edible food through the height of the drought. Jullienna Haiara, at Mougulu, reported that ''sago saved us'' during the months before food aid was delivered and Otty Hawai, at Ga:misi, wrote in his diary that ''we had hungry season in March to November, and we nearly finished the sago palm.'' Extraction of flour from the pith of sago palms, however, requires a good supply of water. In central areas of Bedamuni territory, most of the palms grow in small swamps near the headwaters of streams. After September these streams were dry and opportunities to process available palms were limited. From November, into the early months of 1998, everyone was reliant upon food aid (rice, flour, and cooking oil) that, as possible, they supplemented with wild plant foods (e.g., *Gnetum gnemon* leaves and bamboo shoots) and dwindling stocks of sago.

At Ga:misi, gardens that had been established in 1996 were productive through the first half of 1997. New banana gardens were planted and felled

[4]Our own casual observations, one year after the drought broke, reinforced statements made by local people. In Bedamuni territory, the understorey of (mostly secondary) forest had been invaded, in many places, by grass or bracken fern following extensive defoliation. Moderately extensive fires had burned forest in some places, leeches were uncommon (though, by December 1998, on the increase) and we heard no chorusing frogs. In Kubo territory, in January 1999, walking from Suabi to west of the Strickland River, we detected no overt changes to the understorey of (mostly primary) forest and saw no areas of burnt forest. Leeches were relatively common (though much less so than in earlier years) and we regularly heard chorusing frogs. Note that in October–December 1997 Bickford (1998) observed large, drought-related, reductions in frog populations at Crater Mountain, Gulf Province, Papua New Guinea. Pounds *et al.* (1999; see also Holmes, 1999) have reported major reductions in diversity and abundance of frogs in higher altitude forest of Costa Rica that were correlated with lower annual rainfall and, particularly, years in which dry days were common during winter.

through these months. In April and May *okari* nuts (*Terminalia*) were available in quantity and, in the latter month, two families obtained large harvests of tubers from gardens that had been initiated in September–October 1996. Later tuber harvests were of inferior quantity and quality. In July and August 1997 people commenced clearing sites for a new round of tuber gardens. Some of these areas were fenced but little planting was done and this was unsuccessful. By September the ground was dry and ''too hard to dig'' and gardening projects were abandoned until good rains came in December. At some villages planting stock was secured by transplanting it to moist and sheltered refuges but no-one at Ga:misi did this.

From December 1997, and throughout 1998, all families at Ga:misi spent a great deal of time gardening. They cleared rapidly growing weeds from down-slope areas of older banana gardens to facilitate growth of banana suckers in favorable locations. They established tuber gardens at the same time, though these were three to four months behind schedule. They dug up resprouting banana suckers to plant at new gardens and, in the early months of 1998, contrary to practices observed before the drought, fenced these sites to secure the young plants from pigs that, short of wild forage themselves, had resorted to foods they usually ignored. To accommodate the lengthy delays to harvest of key staples (bananas, taro, yams) they planted crops that would yield more rapidly—corn, cassava and, especially, sweet potato.[5] The last was either interplanted with bananas, planted where forest had accidentally burned, grown in separate small fenced plots, or near houses, in mounds; we had not observed these practices at Ga:misi in 1996. (Beek, 1987, p. 21, wrote that, in the late 1970s, Bedamuni grew sweet potato primarily for use as famine food or for feeding to pigs.) By the middle of 1998 they were harvesting bananas from 1997 gardens that had been reinvigorated and sweet potato from the new plantings of 1998. They then turned to a second round of banana gardens which they did not fence and, in late November and December, commenced a new round of tuber gardens. These latter were still well behind schedule and more closely synchronized across families than was the case 2 years earlier.

Gardens established through the latter half of 1998 reflected an ongoing concern to offset risk by maximizing returns, disperse the sites at which specific crops were planted and collapse different categories of gardening work within the one time frame. Thus, within or adjoining tuber gardens, small ridge-top areas (up to 0.06 ha) were planted with bananas and in moist down-slope areas, often beside streams, minor plots of mixed crops—10

[5]At Ga:misi we were told that, after the drought, with one exception, there was sufficient planting stock of all primary crops. The exception was taro which was scarce, because most planting material had been eaten and none had been secured in moist refuges.

to 15 banana plants and similar numbers of pineapples, taro, and green vegetables—were established. These latter plots were unlikely to yield well if 1999 proved to be a very wet year but would be productive if conditions were relatively dry. In 1998, down-slope areas that hold moisture were disproportionately favored as sites for planting bananas. And the total area planted was larger than in 1996. Thus, the area of tuber gardens (including sweet potato plots) was 4.09 ha in 1996–97 and 5.28 ha in 1998–99. Again, though we lack details of areas of banana gardens in the later period, the number of individually held plots established in 1996 was 23 and the number in 1998 was greater than 30.

By late 1998 people at Ga:misi had harvested tuber gardens planted early in that year, were beginning to get useful yields from banana gardens planted at the same time, were abandoning older banana gardens that they had reinvigorated after the drought, and had established tuber gardens and banana gardens that would produce large harvests in 1999. But at this time they continued to be much more reliant upon sweet potato and cassava than had been the case two years earlier. Sugar cane, which had failed during the drought, was now available in quantity. Lowland *pitpit* (*Saccharum edule*) and *marita* pandanus (*Pandanus conoideus*), which are important feast foods and had also failed during the drought, produced poor returns relative to 1996–97 and the yield from coconuts was low. Sago flour, which had provided an important emergency food through the drought, was scarce in late 1998 relative to 1996–97; it was not used as a staple at this time but, rather, directed towards satisfying the needs of feasts.

Near the Strickland River the effect of the drought on food production systems was far less severe than in Bedamuni territory. We were told that production from gardens was substantially reduced but did not cease. Though yields from bananas declined, some edible fruit, though of inferior quality, was available throughout the drought. Taro gave poor returns but green vegetables, such as *aibika* (*Abelmoshus manihot*), continued to produce edible leaves. Lowland pitpit, sugar and *marita* pandanus were among the worst affected crops, and coconuts, if they ripened, were of very poor quality. Sago palms are very abundant near the Strickland River and, though smaller streams dried out and thus limited locations at which pith could be easily processed, the flour was available throughout the drought.

In this area people commented on local variation in the effects of the drought. Deleterious effects were less pronounced at gardens that were less exposed to the sun—small gardens that were surrounded by forest—and were situated on the banks of larger streams that drained the backswamps. It was at gardens located on the bank of the Strickland River that yields fell most dramatically; here the water table was lower relative to the root systems of crops and the gardens more likely to be surrounded by

areas of low regrowth and, hence, exposed to the sun. We were told that in the later months of 1997, when bananas and taro were under greatest stress, conditions became favorable for sweet potato. For at least 3 months late in that year people did not plant new banana gardens but, rather, planted sweet potato in stream-side plots. Through the early months of 1998 when bananas were relatively scarce, and in contrast to our earlier experience in this area, sweet potato made up much of the shortfall in carbohydrates.

Our own observations indicate that, unlike Bedamuni, people living near the Strickland River did not respond to the arrival of good rains at the end of 1997 by initiating an intense phase of gardening activity. At this time they were receiving food aid. This, in combination with available sweet potato and greatly improved opportunities for processing sago, ensured satisfactory amounts of food. Gradually, through the months January to April 1998, all families established new banana gardens, and these were beginning to yield in quantity by January 1999. Some families restored and maintained older banana gardens that had deteriorated through the drought but this occurred only where those gardens were close to the places where they usually lived. And, late in the year, most families prepared small gardens in which sweet potato was planted as a dominant. As we observed among Bedamuni, one year after the drought broke, sweet potato was a more important food for Kubo-Konai than it had been in earlier years; it was eaten by most families each day. Several people had experimented with mounding and the tubers that resulted were larger and of higher quality than we had seen before.

DOMESTIC PIGS

In Bedamuni territory access to food by domestic pigs became increasingly difficult through the period of the drought. People ceased to provide supplementary food to the animals, which therefore foraged further afield, were less likely to return to their owners at night, and included less preferred items (e.g., banana suckers) in their diet. Domestic pigs in this area were not only stressed by the drought, they were in direct competition with people for food.

At Ga:misi, in January 1997, there were 20 domestic pigs in the care of residents (0.21 pigs/person). Twelve of these were young animals (i.e., less than 20 kg). The domestic pig population was, therefore, small relative to the number of people but in a phase of growth following contributions made to recent initiation ceremonies (cf., Beek, 1987, p. 25). By January 1999, seven of these pigs had been killed and eaten, five had died and one

was 'lost' and presumed to have died. In the same period there were only seven surviving recruits to the domestic pig population to give 0.14 pigs/person. Thus, expected growth in the domestic pig population has been curtailed through the drought and both the number and biomass of pigs were notably less in January 1999 than in January 1997. Further, in December 1998 and January 1999, locally born piglets were being recruited into the village population when, usually, most recruitment is achieved by the exchange of piglets with members of other villages.

In low-lying areas near the Strickland River foraging opportunities for pigs, both wild and domestic, were not seriously jeopardized through the drought. Mature domestic pigs in this area are often provided with the unprocessed pith of sago palms (Dwyer, 1993) and this food source, though perhaps of inferior quality, continued to be available. Piglets that have been taken into care are fed cooked and pre-masticated bananas and, again, though the availability of high quality fruit was reduced access to fruit which was suitable for pigs was probably not in doubt.

At Gwaimasi, in January 1996, there were 30 domestic pigs in the care of residents (0.94 pigs/person); 16 of these were classed as young. By January 1999, 13 of these animals had been killed and eaten and five were ''lost'' and presumed to have run wild. No deaths were reported. In the same period there were 22 surviving recruits to the domestic pig population in the care of families sampled in 1996 to give a total of 1.0 pig/person. Further, the biomass of domestic pigs held in January 1999 was higher than in January 1996. Thus, there is no suggestion that the population of domestic pigs at and near Gwaimasi was seriously affected through the period of drought. Through 13 years people in this area have been steadily increasing the size of domestic pig populations and experimenting with different approaches to management (Minnegal and Dwyer, 1997). The drought had little or no affect on these processes.

ANIMAL FOODS AND PROTEIN

Wild animal foods are not a major quantitative component of Bedamuni diet. Crayfish and small fish provide the most regular sources of animal protein. Small birds, rats, bandicoots, cuscuses, and a variety of insects, together with an occasional wild pig, are additional sources. Beek's (1987) estimates, based on a 21-day survey, were of approximately 3 g protein per person per day from wild pigs and the same amount from other animal foods. The contribution from wild pigs, however, was inflated in that four of eight wild pigs taken in a 9-month period were obtained during those 21 days. Our 1996–97 observations at Ga:misi also indicated a low

intake of animal protein; in fact, most dietary protein was derived from plants, with tulip leaves (*Gnetum gnemon*) and nuts (*Terminalia*, *Canarium*) being seasonally important.

As smaller streams in Bedamuni territory progressively dried though 1997, crayfish became more difficult to catch but opportunities to harvest fish using the poison from derris vine were, initially, enhanced. Ga:misi residents poisoned fish in the nearby river in May 1997 and, later, with people from neighboring villages, they poisoned fish in the larger, more distant and extra-territorial, Rentoul River. They reported that large hauls were obtained, but these were widely distributed and the quantities received by individuals would have provided only minor boosts to a progressively diminishing intake of protein. Indeed, through the drought, irrespective of direct impacts on access to and availability of animal foods, dietary quality will have deteriorated because protein-rich plant foods, both wild and cultivated, ceased production. Data from Ga:misi indicate that domestic pigs were killed for local consumption at a higher rate than usual and that many of the piglets born in this period were eaten rather than retained (or exchanged). By late 1998 small crayfish were again relatively abundant in local streams, small fish were available in rivers and larger streams, peanuts were being grown for local consumption and sale, *galip* nut trees (*Canarium*) had recently produced a large harvest, sufficient coconuts were available for inclusion as shredded pith in feast food (though not for incidental eating) and, at Ga:misi, two wild pigs were shot in the course of three weeks.

Near the Strickland River people obtain much animal protein from a variety of wild sources. Pigs, fish and insect larvae are of particular importance. In 1986–87, at Gwaimasi, the intake of protein from wild vertebrates was more than 40 g per adult per day (Dwyer and Minnegal, 1991). With one exception similar quantities from the same range of species were available through the next nine years. The exception was fish that were obtained by hook and line from the Strickland River. In 1986–87, fish from this river contributed 4–5 g protein per adult per day; they were one of the most regular contributions of protein to diet and an important means whereby women contributed to the production of meat foods (Minnegal, 1994, 1997; Minnegal and Dwyer, 1995). By mid-1995 the frequency of fishing in the river had greatly declined because some of the fish caught were diseased; it was feared that the symptoms were caused by pollution originating from the gold mine at Porgera, 250 km upstream (Minnegal and Dwyer, 1996).

Wild animal foods continued to be available at these communities during the drought. Indeed, people commented on the ease with which they caught large numbers of fish when these gathered in pools as streams began to dry. They also continued to kill large numbers of wild pigs, partly, we suspect, because these animals moved to the backswamps where foraging

prospects were better and, partly, as reported to us, because Gwaimasi village had been virtually abandoned to domestic pigs, and sows that were on heat lured wild boars to open places where they were more easily ambushed. When the drought broke there was a brief period when many fish died in local streams (see above) and people refrained from fishing in these locations. These streams rapidly recovered, however, and, when the Strickland River returned to normal levels, fish were no longer diseased; by early 1999, the river was again an important fishing location. We were told that the fish had recovered because, when the drought was at its height, Porgera had ceased operations and thus stopped polluting the river.

FOOD AID

In late September and early October 1997, thirteen frost and drought assessment teams visited areas throughout Papua New Guinea and categorized the status of the population in each census division on a scale from best to worst of 1 to 5. Category 5 was ''Extreme situation. Only famine food available, and/or water very short, and/or many people ill, and/or small children and old people seriously at risk'' (Allen, 1997; Allen and Bourke, 1997).[6]

Mougulu, representing Bedamuni, was assessed as Category 5 on the basis of poor health, some deaths and very limited and declining availability of garden foods. The situation was judged to be so serious that the leader of the assessment team organized an immediate distribution of food that was sponsored by the Lions Club at the mining town of Tabubil (Schultz, 1997); some of this food was given to local teachers and medical staff so that they would remain at Mougulu (J. Haiara, pers. comm.). The Blucher Census Division, which includes lowland and foothill communities west of the Strickland River, was also assessed as Category 5, primarily on the basis of observations at Gwaimasi (poor quality drinking water, dry gardens, rotting taro, reported limited stocks of sago and two recent deaths) and reported fires at Tinahai, in foothills 20 km north of Ogwatibi, which had destroyed gardens and apparently led to abandonment of that village by

[6]Frost and drought assessments were sponsored by the Australian Agency for International Development (AusAID) and the Papua New Guinea Department of Provincial and Local Government Affairs. We have seen reports and field notes from the first and second assessments, the preliminary report from the third assessment and the ''Review Report on the 1997/98 Drought Relief Operation in PNG'' (Australian Department of Foreign Affairs and Trade); the last includes details concerning delivery of food aid and planting materials to airstrips in the Nomad area. The third assessment, in March 1998, focussed on rehabilitation and recovery needs but, as a result of a helicopter crash, did not visit localities discussed in this article.

more than 100 people. A second drought assessment was conducted in early December 1997 after rains had begun to fall. In the Nomad area only locations with airstrips were visited. Food supply at Mougulu, Suabi, and Dahamo was judged to be extremely poor but improving; water supply was judged to be adequate.

In early November 1997 the first of three or four distributions of food—one per month—was delivered, courtesy of the Australian Agency for International Development (AusAID) and the Australian Defence Force, to airstrips at Mougulu, Suabi and Dahamo (Table I). In March 1998 planting stock was supplied to Suabi, and in response to concerns about an increase in malaria at Mougulu, 2000 mosquito nets and 50 liters of permethrine were delivered to this airstrip.

Mougulu, Suabi, and Dahamo served as food distribution centers for relatively large catchment areas. Thus, Mougulu served all but one isolated Bedamuni settlement, the Etoro community at Dodomono, Halado communities from south of the Rentoul River, but not people from Nomad. The

Table I. Amounts of Aid Delivered to Airstrips at Mougulu, Suabi, and Dahamo in Late 1997 and Early 1998[a]

			Amount Delivered (Tonnes)				
Locality	Pop.[b]	Aid	Nov. 97	Dec. 97	Jan. 98	Feb. 98	Mar. 98
Mougulu	4750	Rice	33.02	38.00	38.00	—	—
		Flour	9.40	9.50	9.50	—	—
		Oil	4.75	4.75	4.75	—	—
		S. pot.[c]	—	—	—	—	—
		Seed	—	—	—	—	—
Suabi	625	Rice	5.00	5.00	5.00	5.00	—
		Flour	—	1.25	1.25	1.25	—
		Oil	—	0.63	0.63	0.63	—
		S. pot.	—	—	—	—	0.375
		Seed	—	—	—	—	0.033
Dahamo	400	Rice	3.22	3.22	3.22	—	—
		Flour	0.80	0.80	0.80	—	—
		Oil	—	0.40	0.40	—	—
		S. pot.	—	—	—	—	—
		Seed	—	—	—	—	—

[a]The populations served by these airstrips were assessed as Category 5 from October 1997 to at least January 1998; Mougulu and Dahamo were reclassified as Category 4 in February 1998; Suabi was reclassified as Category 4 in March 1998. Aid was also delivered to airstrips at Yehebi (Gebusi, once only), Honinabi (Samo, five times) and Debepare (Pare, five times) but not to Nomad (Government Station), Dodomono (western Etoro) or a sparsely populated area (Halado people) southeast of Mougulu and south of the Rentoul River.
[b]Pop. = size of targeted population estimated by AusAID.
[c]S. pot. = sweet potato.

women, men and youths who carried on behalf of the most distant of these communities travelled for two days to receive supplies. Suabi served all Kubo communities north of the Boye River and west to the Strickland River (including Sosoibi), Fẹbi communities north to Tōbi and west to the Strickland River and a small community of Bedamuni, Fẹbi, and Huli people at Gehara near the headwaters of the Boye River. Dahamo served communities in the Blucher Ranges (Tinahai, Gaiyabi, Ogwatibi, and Tagohai), and the lowlands east to the Strickland River (including Soeya Hafi, Gwaimasi, Mome Hafi, and Dimobi). Carriers from Tōbi travelled for 3 days to receive food and 4 days on the return trip; those from Gehara and Tinahai travelled for 2 days to receive food and, perhaps, 3 days on the return trip. Given that food shortages in this region were more serious at higher altitudes it seems that, in areas served by Suabi and Dahamo, those who carried on behalf of the most disadvantaged people travelled furthest to receive supplies. In fact, more distant communities may not have received a share of the last distribution of food aid but this may have been because those people now had sufficient local sources and preferred not to travel long distances for non-essential supplements. Monsef *et al.* (1998) reported that in the Pare Census Division, west of the Strickland River, the percentage of families who reported receiving food aid dropped from 73% in January to 27% in February.

The amounts delivered to food distribution centers were based on an allowance of 8 kg rice, 2 kg flour and 1 liter of cooking oil per person per month. This ration provides 70% of a recommended 2100 kcal per person per day with less than recommended energy from protein and more from fat (Monsef *et al.*, 1998). With the exception of minor shortfalls in November 1997 the amounts of food delivered to Mougulu, Suabi and Dahamo matched targeted amounts based on available understandings of population sizes (Table I). Our judgment is that population sizes were underestimated for Mougulu and Dahamo and overestimated for Suabi but that discrepancies were relatively minor in each case.

Local understandings of sharing influenced patterns of distribution. The distribution from Mougulu aimed to provide food on a per-head basis and was based on a census of village populations conducted by staff of the local Health Sub-Centre. That intention was modified at village or Ward level (a Ward is an administrative unit comprising several villages). Local residents told us that, at Ga:misi, each married man and woman received 20 kg of rice per month and that bachelors shared 40 kg of rice per month. These amounts gave an average of between 6.5 and 8.0 kg rice per person (excluding nursing infants) but the arrangement favored bachelors and, particularly, small families. The bias conformed to patterns of distribution that occur at Bedamuni feasts where shares are allocated to households,

not individuals. With one category of exception, people did not complain to us about the distribution that they themselves had implemented. The exceptions arose because two marriages occurred, and two divorced couples reestablished cohabitation, during the period that food aid was provided. These individuals, particularly the newly weds, received more food at subsequent distributions and some tension and pressure to redistribute resulted. At Suabi and Mome Hafi we were told that, with the exception of small children, individuals received the recommended amounts. These people may, of course, simply have followed the instructions of outsiders who provided food, but this mode of distribution was consistent with patterns of sharing observed by us in 1986–87. Though we have noted a shift towards 'group-level' rather than 'individual' sharing through the 10 years since then (Dwyer and Minnegal, 1998), the arrival of an apparent surplus of food that was not the product of any specific group's land or efforts may well have revived earlier ideals regarding appropriate ways to pattern the distribution of garnered produce.

At Ga:misi, and probably through most of Bedamuni territory, virtually all food provided in at least the first and second distributions was consumed by the time of the next distribution. For most Bedamuni that food provided their primary daily sustenance. This was not the case among Kubo communities at either Suabi or near the Strickland River where some food received as aid was directed to feasts. At Suabi, some of the rice received as aid was held as late as July 1998 (T. Covington, pers. comm.) and at Mome Hafi cooking oil received as aid was still available in January 1999.

Planting stock and seeds were provided to Suabi by the Australian Government and to Mougulu by an unknown donor, but were less widely distributed than food. At Ga:misi most families obtained corn and bean seeds. The corn provided a useful dietary supplement early in 1998; the beans grew well but few people liked them and in December 1998 they were eaten by almost no-one except visiting Europeans. Strickland River communities received corn seed via Suabi; seed potato was also available but under prevailing conditions failed to produce tubers.

In late January and early February 1998 AusAID funded a rapid assessment of the nutritional status of people in areas that had been severely affected during the drought (Monsef *et al.*, 1998). The Nomad District was represented by a sample drawn from communities in the Pare Census Division. A high rate of acute malnutrition was reported. However, local variation in impact of, and responses to, the drought in combination with problems of methodology and standardization suggest that it would be unwise to extrapolate conclusions to Bedamuni and Strickland River communities.

HEALTH AND MORTALITY

By early October 1997, based on information available at the Mougulu Health Sub-Centre, the health of Bedamuni people was judged to be very poor (Wissink, 1997). There had been 11 deaths from whooping cough between April and June, 52 admissions for whooping cough between July and September, 73 admissions with anaemia or pneumonia in August and September, and several cases of food poisoning that resulted from eating wild plants. Most children seen at the Mougulu Child Health Clinic were malnourished.

Reported deaths, and extended periods of illness and hospitalization among older people, were clustered in the later months of 1997 and the early months of 1998. At Ga:misi one adult, one child and one 10 month-old infant died and at least two adults were hospitalized. At two other villages near Ga:misi three and four deaths, respectively, occurred in this period. These deaths were locally attributed to the drought. We were told that, through this period, both old and young people were "just bone, without flesh." In the early months of 1998, after the drought had broken, the incidence of diarrhoea and malaria increased, taking their toll of an already debilitated population (J. Haiara, pers. comm.).

Through the past three decades the size of the Bedamuni population has increased considerably, birth spacing has declined and/or infant survival increased, and at 1996–98, 50% of the population was less than 15 years old. (Beek, 1987, estimated that in 1979, 39% of 174 people were less than 15 years old.) In late 1996, we judged existing food production systems to be under some stress and the health status of the population to be low relative to that of their Kubo neighbors. In particular, the condition of many children, especially those who were mentally or physically handicapped or had lost one or both of their biological parents, was indicative of malnutrition. Our interpretation of the limited information concerning Bedamuni, is that, with respect to health, the drought aggravated a situation which was already poor.

During 1997, and until at least January 1999, Medical Aid Posts at Suabi, within Kubo territory, and Dahamo, within Konai territory were without staff. Thus, we have no formal health statistics relevant to Strickland River communities through the period of the drought. A medical survey in the area in January 1996 judged health to be poor (Anon, 1996). Our own observations over 13 years are that parasite levels (malaria, hookworm, filariasis) are high, child mortality rates are high but decreasing (14 deaths in 53 recorded births between August 1986 and January 1999), and that the incidence of malnutrition in children has increased in parallel with reduced birth spacing and higher birth rate (from August 1986 to January

1999 the proportion of the population less than 15 years old increased from 0.31 to 0.39; $n = 78$ and 114, respectively). Against this background any added stress would be expected to increase morbidity but, in small samples, be difficult to detect. In the Strickland River population mortality rate, especially of children, was high between January 1996 and January 1999. In that period there were eight deaths (six children and two adults) in a starting population of 102 residents. In January 1999 residents of these communities did not suggest that the drought led to higher rates of illness or mortality; nor would we have expected them to do so because, to them, sorcery will have been the primary cause of each of those deaths.

MOBILITY

Among Bedamuni both temporary and long-term relocations occurred during 1997. These were prompted either directly by considerations of access to sources of water for drinking, cooking, or processing sago or indirectly by intracommunity tensions that were themselves aggravated by the drought. Throughout the latter half of 1997, families from Ga:misi (especially those with young children) spent extended periods living at bush houses or in the open beside the only river that continued to supply reliable running water. And, by late 1997, 18 people had relocated to a new longhouse to establish a satellite community at Faugali, 20 min walk to the south. One year later they were still based at this location. Similar short- and long-term relocations were reported from other Bedamuni communities (e.g., Habi, Mougulu and Sedado; see Fig. 1). Drought-related residential shifts among Bedamuni were not prompted by considerations of access to food except in as much as proximity to more reliable water sources facilitated processing of sago. And movements that did occur were less than three kilometres; they did not take people beyond areas in which they usually satisfied subsistence needs.

Between January 1996 and January 1999 Kubo and Konai people living near the Strickland River changed residence at a higher rate than had occurred through the previous 10 years. In the earlier period individuals changed residence, on average, once in 5.9 years (Minnegal and Dwyer, in press); in the later period they changed residence, on average, once in 3.9 years ($n = 52.2$ and 69.6 individuals respectively; number of individuals standardized against duration of residence within the study area; children and movements entailing immigration to study area excluded). Most movements after January 1996 (62% of 112) were associated with establishing a new village at Mome Hafi that eventually attracted most residents of Gwaimasi, all residents of Sosoibi, and others from beyond this area. By January

1999 the population of Mome Hafi was 60 people; in the previous 12 years no village in this area had attained a population size greater than 42 people.

Former residents of Gwaimasi who had relocated to Mome Hafi during 1997 said that access to water for drinking, cooking and washing influenced their decision to move. They drew explicit connections between these problems and the drought. Gwaimasi, in fact, was poorly located with respect to water for drinking and cooking and, in the context of an up-river mining venture, growing concerns about the quality of the Strickland River made this a less attractive site for washing. However, while relocation to Mome Hafi will have greatly improved access to water it is doubtful that the drought was primary in motivating the move. It is of more significance that the three families who did not move to Mome Hafi, asserting continued allegiance to Gwaimasi, established gardens and substantial houses away from the latter village at locations close to reliable water sources. Through the months when the drought was at its height, and subsequently as they reestablished gardens, these people apparently spent little time at Gwaimasi. Rather, that village site was visited on a temporary basis by others who had left domestic pigs there when they relocated to Mome Hafi.[7]

Through the period that Mome Hafi was established one man, his two wives, four of his children, and his half-brother relocated from Soeya Hafi to Dimobi where they established gardens and lived in a bush house. This move was to land where the man and his half-brother held unambiguous rights of ownership to resources and where, therefore, access to sago resources was secure. In January 1999 these people moved back and forth between Dimobi and Soeya Hafi and their residential arrangements were in flux.

In addition to the local residential shifts described above there were movements by other people into the area that were motivated by considerations of access to more reliable food resources. These movements, by three married couples and six bachelors, were of up to 30 km and were from higher to lower altitudes where sago palms were more abundant, access to water for processing sago was more secure and hunting and fishing prospects were better. None of the relocating individuals had been a resident of Sosoibi, Gwaimasi or Soeya Hafi (or the villages from which these derived) in the previous 11 years. Their movements took them beyond areas in which they had usually satisfied subsistence needs and, in contrast to relocations out of the area in the same period, were not motivated by demographic considerations (e.g., marriage, death). We recorded no analogous residen-

[7]In late September 1997, people present at Gwaimasi reported using water from the Strickland River for drinking; the water tested positive, within 20 min, for fecal coliform bacteria. (D. Wissink, 1997, pers. comm.). The river was not used as a source of drinking water during our visits between 1986 and 1996.

tial shifts between 1986 and 1996 (Minnegal and Dwyer, in press). One of the married couples and three of the bachelors returned to their former places of residence after the drought had broken.

The different patterns of movement in response to drought among Bedamuni and Kubo-Konai reflect, at least in part, the constraints imposed by local systems of tenure and use rights. Among Bedamuni, rights to use land are defined by birth, in the case of men, and by marriage in the case of women. Access to resources on the land of others is subject to invitation by owners, invitations that are less likely to be forthcoming in times of stress. Among Kubo, in contrast, rights to use land are accorded on the basis of past patterns of use. Access to resources is nominally open to all, subject only to a requirement that non-owners first ask permission of those most closely associated with the resources in question, permission that cannot easily be denied (Dwyer and Minnegal, 1999). While Bedamuni had little choice other than to disperse to the remaining patches of food (or water) on their own land, Kubo-Konai were free to congregate on the land of others where food was more abundant.

SOCIAL LIFE

At the Bedamuni village of Ga:misi, in December 1998, social life did not always match understandings that we had reached two years earlier. We think that the drought was implicated as a proximate factor in these differences.

Fission of the Ga:misi community during 1997 was connected to a long-standing dispute concerning rights to land. The tension associated with this was, it seems, aggravated through the drought and could not be resolved by conventional means of dispute resolution which, among Bedamuni, favor negotiation over exit (Minnegal and Dwyer, 1998). The level of intra-community tension was high in December 1998 with six instances where violence erupted between co-wives and between an unmarried man and his mother, and plans were afoot to encourage the departure of one long-term resident who did not own land near the village. In all these cases the difficulties had persisted for at least several months and, at least in part, implicated perceived problems with respect to access to resources, contributions to subsistence work and sharing. The difficulties were formally acknowledged when the man appointed as village ''Committee'' announced that everyone had worked very hard through the year, that Christmas was approaching, and that all should cease work at gardens (other than for harvesting) and relax. They were acknowledged also at dawn on New Year's Day when, for nearly three hours, most residents of Ga:misi and four from

the recently formed satellite community at Faugali held an 'ash fight'; they released tension by throwing (and rubbing) ash, mud, red pandan oil, and pig feces at (and on) each other, abandoning conventional restraints of interaction and contact between older and younger, male and female, married and unmarried (Dwyer and Minnegal, in press).

Intra-community tensions at Ga:misi spilled over to relationships between communities when, on two unrelated occasions in December 1998, the close kin of one protagonist in an intra-village dispute arrived—once armed with fighting sticks—to assess the problem and if necessary intervene. But relationships between communities were tense for other reasons that were more directly connected with the drought. Deaths that had occurred late in 1997 and early in 1998 had heightened concerns with sorcery (cf., Stewart and Strathern, 1998) and people were uncomfortable or fearful when visiting neighboring communities. In addition, feast foods were badly affected through the drought and slow to reestablish through 1998; these included lowland *pitpit*, coconuts, sago flour, crayfish, beetle larvae that are incubated in portions of sago palms, and domestic pigs.[8] Their scarcity through that year reduced opportunities for affirming relationships of goodwill with affines living at other communities.

Between 1996 and 1998 at Ga:misi there were changes in the places where people made their gardens and in the combinations of people who gardened together. In 1996, with one exception in a sample of 41 garden plots, male residents of the three land-owning clans at Ga:misi established plots on their own clan land and male residents who were not local landowners established plots on the clan lands of land-owning residents. In 1998, in a sample of 38 garden plots, there were seven cases in which these patterns were disrupted because either land-owning residents gardened on the land of a resident clan other than their own or non-land owning residents gardened on the land owned by males of a neighboring village. The difference between years is significant ($\chi^2 = 5.3$, $P < 0.025$). These changes were influenced by difficulties of access to land that had emerged for non-owning male residents, post-drought preferences with respect to down-slope garden sites, and invitations to share in gardening ventures which might serve to ameliorate tension between members of Ga:misi village and its breakaway satellite community.

Near the Strickland River we did not detect impacts of drought on social life other than alterations to patterns of dyadic interaction arising as an inevitable outcome of changes in residential arrangements. Certainly

[8]At Ga:misi the absence of edible beetle larvae at any time during December 1998 and particularly at a feast held in early January 1999 was itself evidence that few, if any, sago palms had been processed 2 to 3 months earlier.

there was little evidence of the intra- and inter-community tension observed among Bedamuni. This may well reflect the greater freedom that Kubo have to resolve disputes by exit, moving away from a source of tension; Bedamuni, with limited access to resources elsewhere, must resolve disputes through negotiation so as to allow both parties to remain in the community. It should be emphasized that in neither population was there evidence that additional work entailed, for example, in carrying water during the drought, had fallen disproportionately upon women (cf., Allen and Bourke, 1997). There was no marked increase in tension between spouses as a result of the drought, even at Ga:misi. Indeed, given the emphasis on gender equality that characterizes this region we would not have expected inequities of that kind to emerge here.

DISCUSSION

The El Niño-related drought of 1997 had much more serious effects upon Bedamuni than upon Kubo and Konai communities living near the Strickland River. These two areas of the interior lowlands of Papua New Guinea are only 60 km apart and experience similar climatic conditions. Altitudinal differences are minor but correlate with others of topography and drainage and with choices people make with respect to garden locations (cf., Sillitoe, 1999). In the first instance, therefore, the impact of drought on life support systems may be traced to interactions between local geographic circumstances and prevailing subsistence modes. But subsistence modes are themselves intimately connected to sociality and ethos which, in turn, influence ways in which people respond to and structure recovery from environmental crises.

In the hilly terrain of Bedamuni territory, ridge tops and upper slopes are favored as sites for gardens. Here run off is relatively high and the soil less likely to be waterlogged. But in 1997, upper slope locations were exposed to sustained higher temperatures; the ground dried and, later in that year, was not adequately replenished by rain. It was the location and exposure of these garden sites that led to collapse of yields; it was not the inherent vulnerability of the mix of crops grown, for this was essentially the same as found near the Strickland River. Indeed, in the year that followed the drought, people altered their choice of gardening locations by favoring down-slope locations and moist refuges to a much greater extent than before.

Kubo-Konai communities living near the Strickland River favor levee banks of the river and larger streams as garden locations; less often they use minor rises within the backswamps. Their choice of these sites, rather

than nearby and suitable foothill locations, is influenced by proximity to abundant sago resources and fishing opportunities. The consequences are that the water table is high relative to the root systems of crops, that drainage is poor and that, in circumstances of exceptionally high rainfall, garden productivity may be impaired. But this choice of garden locations stood the people in good stead through the drought. As conditions deteriorated for major crops such as bananas and taro they improved markedly for sweet potato and, if seeds were available, beans and corn; these three latter crops have much shorter times to yield than do the usual staples. Further, banana gardens that had been established in lower lying situations and were surrounded by forest continued to yield throughout the drought; during the first half of 1997 they may have performed better than they would otherwise have done.

Topography, drainage and the places where sago palms grow also influenced differences between Bedamuni and Kubo in availability of sago flour through the drought. Most sago palms in central Bedamuni territory grow in relatively small swampy areas near the headwaters of minor streams. Here, as the yield from gardens fell through the earliest phase of the drought, sago palms provided an important emergency food. But as the drought progressed the availability of mature palms that would yield good quantities of flour declined and the places where palms grew became dry so that water, which is needed to extract flour, was accessible only if pith from the palms was carried considerable distances. It is our understanding that this was seldom done, but perhaps only because the people received food aid before it was unavoidable. Near the Strickland River sago palms are abundant. The location of most wild palms in backswamps which, under the canopy of primary forest, retained moisture, and their proximity to larger streams which held substantial pools of water, in combination with established techniques for storing flour (Dwyer and Minnegal, 1994), served to ensure an on-going supply of sago flour through the drought. Both quantity and quality of sago flour will have been reduced at the height of the drought, but at all times, some was available.[9]

With respect to animal foods, the water-holding capacities of backswamps, the enhanced foraging opportunities available to wild pigs in this habitat, the role of intact canopy in maintaining humidity in primary forest, and the fact that the abundance and diversity of larger species of fish declines rapidly with increasing altitude, will have all contributed to the more favorable position of Strickland River communities relative to Beda-

[9]At the predominantly Etoro village of Dodomono, 17 km ENE of Ga:misi, sago flour was available in December 1997 but was described by a member of the drought assessment team as being of "poor quality" and "stinking."

muni through the period of drought. But, in addition, the higher population density and proportion of anthropogenic habitats in Bedamuni territory are causally implicated in the fact that their intake of animal protein is generally low.

The foregoing acknowledges the role of environment in patterning subsistence possibilities but, simultaneously, emphasizes choices people make within the context of existing constraints. The importance of conventional choices to people's experience of the drought may be reinforced by imagining that they lived in others ways. If Bedamuni, for example, had chosen a more dispersed life style, living and gardening in valleys, near rivers, then, while in most years they would have done more poorly than is currently the case, they would probably have been more secure through the drought. By contrast, near the Strickland River, if Kubo-Konai had chosen to live and garden in the foothills then they may have done better in most years, at least in terms of garden productivity, than is currently the case, but would certainly have been less secure through the drought. These speculative differences may be expressed more formally. Bedamuni have adopted a risk prone strategy that provides high returns on effort in most years but has severe deleterious consequences in some years. Communities living near the Strickland River have adopted a risk averse strategy under which they forego potentially higher returns in most years for the security afforded in years when food production is placed in jeopardy. This characterization is that expected of more and less intensified systems of food production—of, for example, farmers versus hunter-gatherers—where cost-benefit considerations prioritize security of tenure in the first case and security of supply in the second (e.g., Winterhalder, 1990). Though both Bedamuni and Kubo-Konai are horticulturalists, they differ in relative commitment to delayed-return production systems, and in the intensity of use they make of land. Further, the theoretically-grounded expectation that these two populations would respond to disruptive events in different ways was supported by the fact that drought-related movements among Bedamuni led to dispersion and among Kubo-Konai to aggregation; in the first case people relocated, at least temporarily, to scattered more favorable locations on their own land, in the latter case they moved to altitudes and habitats where food resources were concentrated, irrespective of ownership.[10]

[10]Febi are a small and highly dispersed population living in foothills to the north of Kubo and at altitudes similar to Bedamuni. In the extent of both agricultural intensification and social complexity Febi are more like Kubo-Konai than Bedamuni and, like the former, responded to the drought with movements that led to increased aggregation. Those movements placed people closer to water, sago resources and less exposed gardening locations.

"Mobility patterns . . . distribute people both temporally and spatially in relation to available resources, establish and limit opportunities to respond to unforeseen events, and establish and represent the networks of relationships through which each individual is connected with others in an always dynamic system of social engagement" (Minnegal and Dwyer, in press). Here, then, is one expression of the connections between both ethos and prevailing social form and ways in which people respond to normal and extreme environmental circumstances. The life-ways of Strickland River communities, for example, are patterned around an expectation that the availability of resources will be often in flux. This is reflected in their emphasis on immediacy in production and exchange, with an accompanying lack of commitment to particular places and relationships. Among Bedamuni, in contrast, a greater acceptance of delay in production and exchange, and non-negotiable identification with their own or their husband's natal land, reflect an expectation of reliability in access to resources. The difference in expectations is reflected, too, in a greater differentiation of roles and statuses by age and gender, elaboration of mechanisms that facilitate intercommunity cohesion, and emphasis on exegesis with reference to at least practical concerns, among Bedamuni relative to Kubo-Konai.

These differences of ethos and sociality between Bedamuni and Kubo-Konai are manifest as distinctions in processes of differentiation, integration and evaluation that underlie our identification of the former as a more complex, and potentially more vulnerable, society than the latter (Minnegal and Dwyer, 1998). And it is within the context of existing socioeconomic systems that people will experience, respond to and pattern recovery from major climatic aberrations (e.g., Hewitt, 1983, 1997; Watts, 1983, 1988). It is here, then, that the present study illustrates the theoretical perspectives advocated by Watts and Hewitt; that vulnerability and response to drought are likely to reflect capacities inherent in social systems and that external responses to potential crisis situations must acknowledge the important but culturally variable role of these intrinsic factors in mediating the implementation and effectiveness of local coping strategies.

The different immediate and longer term impacts of the drought of 1997 upon Bedamuni and Strickland River communities, and their responses to those impacts, were not merely an outcome of different environmental circumstances, population densities, or subsistence regimes. They arose within the context of prevailing social forms and of understandings people held with respect to relationships with both environment and other people. To the extent that Bedamuni, more than Kubo-Konai, understood those relationships as, in the first case, ensuring favorable returns on effort and, in the second, hedged with constraints, so we may appreciate that an encounter with forces beyond the range of the expected—though not necessarily

beyond the range of the known or conceivable—posed a greater threat to the former population than it did to the latter.

CAVEAT

We have concluded that the food production systems of Bedamuni were severely affected through the drought of 1997. Without the continuous presence of medical facilities more people would have died. Without access to food aid they would have made further inroads into available sago palms, jeopardizing the future availability of this source of emergency and feast food for perhaps five or more years. Again, without food aid, some movement beyond usual subsistence zones may have occurred, perhaps to the peripheries of Bedamuni territory where population densities are lower.

We have concluded also that the food production system of Kubo and Konai, though impaired, did not collapse through the drought and that existing coping mechanisms served the people well through this period of stress. For the particular communities where we have worked for 13 years the provision of food aid was a useful, but probably not essential, contribution at a time when usual garden staples gave poor returns. For neighboring communities at higher altitudes, west and east of the Strickland River, the provision of food aid probably reduced movements to lower elevation locations near backswamps.

The situation of both populations through the drought would have been much more serious if, as occurred further south, extensive fires had invaded forest and destroyed stands of sago palms. Droughts will vary in their impact on life-support systems, affecting them in different ways at different times and places. A single comparative study of people's responses to a single drought cannot pre-determine decisions that would need to be taken by outsiders who design and implement relief operations in the event of future droughts. It can merely inform the observations and understanding of those who, on the ground and at the time, assess the needs of affected people (cf., Salafsky, 1994). As Allen (1997) emphasized, in the closing years of the 20th century and at the beginning of the twenty-first, people's responses to shortfalls in food supply are conditioned not merely by past historical experiences and past coping mechanisms, but rather within a frame of changing circumstances, expectations and social forms that arise through incorporation within modern nation states.

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REFERENCES

Allen, B. J. (1997). An assessment of the impact of drought and frost in Papua New Guinea in 1997. *PLEC News and Views* 9: 21–28.

Allen, B. J. (1998). El Niño and the drought in Papua New Guinea. *The Asia-Pacific Magazine* 9/10: 39–42.

Allen, B. J., and Bourke, R. M. (1997). Report of an assessment of the impacts of frost and drought in Papua New Guinea. Port Moresby: Australian Agency for International Development. [Available at http//www.ausaid.gov.au/publications/general/other/pngdroughtrep1.pdf]

Allen, B. J., Bourke, R. M., with Burton, J., Flew, S., Gaupu, B., Heia, S., Igua, P., Ivahupa, S., Kanau, M., Kokoa, P., Lillicrap, S., Ling, G., Lowe, M., Lutulele, R., Nongkas, A., Poienou, M., Risimer, J., Sheldon, R., Sowei, J., Ukegawa, K., Willson, N., Wissink, D., and Woruba, M. (1998). Report of an assessment of the impacts of frost and drought in Papua New Guinea—Phase 2. Port Moresby: Papua New Guinea Department of Provincial and Local Government Affairs with Australian Agency for International Development. [Available at http//www.ausaid.gov.au/publications/general/other/pngdroughtrep2.pdf]

Allen, B. J., Hide, R. L., Bourke, R. M., Akus, D., Fritsch, R., Grau, R., Ling, G., and Lowes, E. (1993). Western Province: text summaries, maps, code lists and village identification. Canberra: Department of Human Geography, Research School of Pacific and Asian Studies, The Australian National University.

Anon. (1996). *Porgera Joint Venture*: *Review of Riverine Impacts*, CSIRO Environmental Projects Office, Dickson, ACT, Australia:

Beek, A. G. van (1987). The way of all flesh: Hunting and ideology of the Bedamuni of the Great Papuan Plateau (Papua New Guinea). Ph.D. Thesis, University of Leiden.

Bellamy, J. A. (1986). Papua New Guinea inventory of natural resources, population distribution and land use: handbook. Natural Resources Series No. 6. Canberra: CSIRO Division of Water and Land Resources.

Bickford, D. (1998). Frog populations affected by El Niño Southern Oscillation event in Papua New Guinea. Abstracts of the Society for Conservation Biology, Macquarie University, Sydney, July 13–16, 1998.

Bourke, R. M. (2000). Impact of the 1997 drought and frosts in Papua New Guinea. In R. H. Grove, and J. Chappell (eds.), *El Niño: History and Crisis.* White Horse Press, Cambridge, pp. 149–170.

Corbett, J. (1988). Famine and household coping strategies. *World Development* 16: 1099–1122.

de Garine, I., and Harrison, G. A. (eds.) (1988). *Coping with Uncertainty in Food Supply.* Clarendon Press, Oxford.

Dwyer, P. D. (1990). *The Pigs that Ate the Garden*: *A Human Ecology from Papua New Guinea*, University of Michigan Press, Ann Arbor.

Dwyer, P. D. (1993). The production and disposal of pigs by Kubo people of Papua New Guinea. *Memoirs of the Queensland Museum* 33: 123–142.

Dwyer, P. D., and Minnegal, M. (1991). Hunting in lowland tropical rainforest: Towards a model of non-agricultural subsistence. *Human Ecology* 19: 187–212.

Dwyer, P. D., and Minnegal, M. (1992). Ecology and community dynamics of Kubo people in the tropical lowlands of Papua New Guinea. *Human Ecology* 20: 21–55.

Dwyer, P. D., and Minnegal, M. (1993). Banana production by Kubo people of the interior lowlands of Papua New Guinea. *Papua New Guinea Journal of Agriculture*, *Forestry and Fisheries* 36: 1–21.

Dwyer, P. D., and Minnegal, M. (1994). Sago palms and variable garden yields: A case study from Papua New Guinea. *Man and Culture in Oceania* 10: 81–102.

Dwyer, P. D., and Minnegal, M. (1998). Waiting for company: Ethos and environment among Kubo of Papua New Guinea. *The Journal of the Royal Anthropological Institute* 4 (N.S.): 23–42.

Dwyer, P. D., and Minnegal, M. (1999). The transformation of use rights: A comparison of two Papua New Guinean societies. *Journal of Anthropological Research* 55: 361–383.

Dwyer, P. D., and Minnegal, M. (in press) El Niño, Y2K and the short fat lady: Drought and agency in a lowland Papua New Guinean community. *Journal of the Polynesian Society.*

Dwyer, P. D., Minnegal, M., and Woodyard, V. (1993). Konai, Febi and Kubo: The northwest corner of the Bosavi language family. *Canberra Anthropology* 16: 1–14.

Ernst, T. M. (1984). Onabasulu local organization. Ph.D. Dissertation, University of Michigan.

Hewitt, K. (1983). The idea of calamity in a technocratic age. In K. Hewitt (ed.), *Interpretations of Calamity*: *From the Viewpoint of Human Ecology*, Allen and Unwin, Boston, pp. 3–32.

Hewitt, K. (1997). *Regions of Risk*: *A Geographical Introduction to Disasters*, Longman, Essex.

Holmes, B. (1999). Heads in the clouds. *New Scientist* 162(2185): 32–36.

Horowitz, M. M. (1990). Donors and deserts: The political ecology of destructive development in the Sahel. In R. Huss-Ashmore, and S. H. Katz (eds.), *African Food Systems in Crisis*: *Part Two: Contending with Change*, Gordon and Breach, London, pp. 3–28.

Huss-Ashmore, R., and Katz, S. H. (eds). (1990). *African Food Systems in Crisis*: *Part Two*: *Contending with Change*, Gordon and Breach, London.

Jipp, P. H., Nepstad, D. C., Cassell, D. K., and de Carvalho, C. Reis. (1998). Deep soil moisture storage and transpiration in forests and pastures of seasonally-dry Amazonia. *Climatic Change* 39: 395–412.

Kelly, R. C. (1977). *Etoro Social Structure*: *A Study in Structural Contradiction*, University of Michigan Press, Ann Arbor.

Kelly, R. C. (1993). *Constructing Ineqauality*: *The Fabrication of a Hierarchy of Virtue among the Etoro*, University of Michigan Press, Ann Arbor.

Knauft, B. M. (1985a). Ritual form and permutation in New Guinea: Implications of symbolic process for socio-political evolution. *American Ethnologist* 12: 321–340.
Knauft, B. M. (1985b). *Good Company and Violence*: *Sorcery and Social Action in a Lowland New Guinea Society*, University of California Press, Berkeley.
McAlpine, J. R., Keig, G., and Short, K. (1975). Climatic tables for Papua New Guinea. *CSIRO Division of Land Use Research Technical Paper* 37: 1–177.
Minnegal, M. (1994). Fishing at Gwaimasi: The interaction of social and ecological factors in influencing subsistence behaviour. Ph.D. Thesis, University of Queensland.
Minnegal, M. (1997). Consumption and production: Sharing and the social construction of use-value. *Current Anthropology* 38: 25–48.
Minnegal, M., and Dwyer, P. D. (1995). Production of fish at Gwaimasi village, Western Province, Papua New Guinea. *Science in New Guinea* 21: 27–40.
Minnegal, M., and Dwyer, P. D. (1996). Changes in fish and fishing in the Strickland River at Gwaimasi Village, Western Province, Papua New Guinea. (Unpublished manuscript.).
Minnegal, M., and Dwyer, P. D. (1997). Women, pigs, God and evolution: Social and economic change among Kubo people of Papua New Guinea. *Oceania* 68: 47–60.
Minnegal, M., and Dwyer, P. D. (1998). Intensification and social complexity in the interior lowlands of Papua New Guinea: A comparison of Bedamuni and Kubo. *Journal of Anthropological Archaeology* 17: 375–400.
Minnegal, M., and Dwyer, P. D. (1999). Re-reading relationships: Changing constructions of identity among Kubo of Papua New Guinea. *Ethnology* 38: 59–80.
Minnegal, M., and Dwyer, P. D. (in press). A sense of community: Sedentary nomads of the interior lowlands of Papua New Guinea. *People and Culture in Oceania.*
Monsef, E., with Gunua, T., Alois, G., Ragin, A., Keko, M., Jacklas, E., Cosmos, Vero, J., Simon, J., Minie, A., Ope, E., Paikara, D., Lasone, M., Stanley, T., Aaron, L., Wagwa, S., Lari, J., Viru, M., Haine, J., Giru, V., Kundal, J., and Lapai, B. (1998). Nutrition and food security assessment of 9 "Category 5" districts during 1997–98 drought/frost in Papua New Guinea: [Overseas Project Commission of Victoria.] Australian Agency for International Development.
Pounds, J. A., Fogden, M. P. L., and Campbell, J. H. (1999). Biological responses to climate change on a tropical mountain. *Nature* 398: 611–615.
Salafsky, N. (1994). Drought in the rain forest: Effects of the 1991 El Niño-southern oscillation event on a rural economy in West Kalimantan, Indonesia. *Climatic Change* 27: 373–396.
Schultz, D. (1997). Feeding frenzy. *The Bulletin* (November 18, 1997): 32–34.
Shaw, R. D. (1986). The Bosavi language family. *Pacific Linguistics Series A*, 70: 45–76.
Shaw, R. D. (1990). *Kandila*: *Samo Ceremonialism and Interpersonal Relationships*, University of Michigan Press, Ann Arbor.
Sillitoe, P. (1999). Where to next? Garden site selection in the Papua New Guinea highlands. *Oceania* 69: 184–208.
Sørum, A. (1980). In search of the lost soul: Bedamini spirit seances and curing rites. *Oceania* 50: 273–296.
Sørum, A. (1982). The seeds of power: Patterns in Bedamini male initiation. *Social Analysis* 10: 42–62.
Sørum, A. (1984). Growth and decay: Bedamini notions of sexuality. In Herdt, G. H. (ed.), *Ritualized Homosexuality in Melanesia*, University of California Press, Berkeley, pp. 318–336.
Sørum, A. (n.d.). The forked branch: A study of meaning in Bedamini ceremonial. (Unpublished manuscript.)
Stewart, P. J., and Strathern, A. (1998). Witchcraft, murder, and ecological stress: A Duna (Papua New Guinea) case study. Centre for Pacific Studies Discussion Paper Series, No. 4, 1998. Townsville, James Cook University of North Queensland: 1–32.
Still, C. J., Foster, P. N., and Schneider, S. H. (1999). Simulating the effects of climate change on tropical montane cloud forests. *Nature* 398: 608–610.
Waddell, E. (1983). Coping with frosts, governments and disaster experts: Some reflections based on a New Guinea experience and a persual of the relevant literature. In K. Hewitt

(ed.), *Interpretations of Calamity*: *From the Viewpoint of Human Ecology*, Allen and Unwin Inc., Boston, pp. 33–43.

Watts, M. (1983). On the poverty of theory: Natural hazards research in context. In Hewitt, K. (ed.), *Interpretations of Calamity*: *From the Viewpoint of Human Ecology*, Allen and Unwin Inc., Boston, pp. 231–262.

Watts, M. (1988). Coping with the market: Uncertainty and food security among Hausa peasants. In de Garine, I., and Harrison, G. A. (eds.), *Coping with Uncertainty in Food Supply*, Clarendon Press, Oxford, pp. 260–289.

Watts, M. J., and Bohle, H. G. (1993). The space of vulnerability: The causal structure of hunger and famine. *Progress in Human Geography* 17: 43–67.

Winterhalder, B. (1990). Open field, common pot: Harvest variability and risk avoidance in agricultural and foraging societies. In E. A. Cashdan (ed.), *Risk and Uncertainty in Tribal and Peasant Economies*, Westview Press, Boulder, pp. 67–87.

Wissink, D. (1997). Summary report to National drought and frost assessment committee: middle and upper Western Province and Telefomin District, Sandaun Province (unpublished manuscript).