

Millennium Ecosystem Assessment

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Sub-global Working Group State of the Assessment Report Lihir, Papua New Guinea

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Sub-Global Assessment of Coastal, Small Island
and Coral Reef Ecosystems in Papua New Guinea

Local Assessment of the Lihir Island Group

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1 Introduction

The case study reported here is part of an assessment of 'coastal, small island and coral reef ecosystems' in Papua New Guinea (PNG), which is being undertaken by a team of scientists coordinated by staff at the Australian National University and the University of Papua New Guinea. The first phase of the assessment (due for completion in 2005) is a nationwide survey of the relationship between coastal communities and coastal ecosystems, with a number of local-level case studies of this relationship (see Figure 1). The second phase (due for completion in 2007) will focus on community-based assessments in one of the case study areas. This second phase is an integral component of the Milne Bay Community-Based Coastal and Marine Conservation Project (MBCP), which is being implemented by the UN Development Programme and executed by Conservation International.

Figure 1: Local assessment sites in Papua New Guinea, including Lihir island group. [INSERT]

The Lihir island case study is the first of the local case studies to be completed in the first phase of the assessment. That is primarily because the authors are familiar with both the conceptual framework of the Millennium Assessment (MA) and with the body of evidence on which the assessment is based. Two of the authors (Filer and Foale) are members of the MA Sub-Global Working Group, and all three have been heavily involved in the assessment and monitoring of the social and environmental impacts of the mining operation which is a major driver of ecosystem change in the Lihir island group (Filer and Jackson 1989; Filer 1995; Filer and Mandie-Filer 1998; Macintyre and Foale 2000, 2001, 2003, 2004a,b).

This local assessment has been structured in the same way as the summary national assessment for PNG as a whole (Filer et al. 2004). Both assessments are intended to test and refine elements of the MA conceptual framework (MEA 2003), and to inform and expand upon the report of the Sub-Global Working Group. Readers should refer to the summary national assessment for explanation of the specific conceptual framework and terminology developed by the PNG assessment team.

2 User Engagement and Data Collection

The Lihir island group is one of several groups of small islands in New Ireland Province, and one which has attained a certain notoriety because of the development of a large-scale gold mine on the eastern side of Niolam, the largest island in the group with an area of 203.4 km². There are four much smaller islands in the Lihir group, with a combined area of only 17.4 km², three of which (Malie, Masahet and Mahur) have much higher population densities than the main island. The local inhabitants group these smaller islands under a single name (Ihot) which refers to the rocky nature of their terrain.

Plate 1: Composite aerial photograph of Niolam island, showing the mine site and mining township. [INSERT]

Plate 2: Aerial view of the mine pit, with Luise Harbour in the background. [INSERT]

Plate 3: Aerial view of Londolovit township, with the small islands of Ihot in the background. [INSERT]

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- 1 Niolam's gold deposits were first discovered in 1983, mine construction began in 1995,
- 2 and the first gold was exported in 1997. The mine is owned by Lihir Gold Ltd and
- 3 operated by the Lihir Management Company (LMC), which is a subsidiary of Rio Tinto.
- 4 Gold exported from this mine currently accounts for about 10 percent of PNG's total
- 5 export earnings. Mining of the original deposits is expected to continue until 2012, after
- 6 which the company plans to mine the accumulated stockpiles of low-grade ore for another
- 7 20 years.

- 8 There are two obvious reasons for conducting an assessment of the coastal ecosystems of
- 9 Lihir and their capacity to provide for the local population. The first is the dramatic
- 10 impact of industrial development on the relationship between the local community and
- 11 the local environment, and the question thus posed about the future impact of mine
- 12 closure. The second is the quantity of scientific information which the developers and
- 13 their consultants have collected in the process of predicting, monitoring and managing
- 14 this impact.

- 15 The mine's operators and managers are obliged to seek sustainable social, economic and
- 16 environmental outcomes for the local community under the terms of their development
- 17 agreements with other stakeholders, including organisations which represent the
- 18 community itself. However, the mining company is the only local user which has so far
- 19 been effectively engaged in the local process of ecosystem assessment. The Lihir Mining
- 20 Area Landowners Association and the Nimamar (Lihir) Local-Level Government have
- 21 shown less interest in the process than community organisations in other areas where a
- 22 process of community assessment has been initiated. Lihirians are currently inclined to
- 23 believe that 'environmental management' is a problem for which the company alone
- 24 should be responsible, because the company is responsible for creating it in the first place.

- 25 Local community leaders have been able to extract a significant proportion of the value of
- 26 the local gold exports in the form of an 'integrated benefits package' which is meant to
- 27 compensate the community for the social and environmental impact of the mine. Their
- 28 understanding of the social impact of the mine is framed primarily in terms of the need to
- 29 defend local 'custom', where the word 'custom' is used to refer to the elaborate mortuary
- 30 feasts through which clans compete to honour the names or memories of their respective
- 31 'big men'. These mortuary feasts are part of a ceremonial economy which also includes a
- 32 variety of Christian festivities, and this ceremonial economy has its own environmental
- 33 impact, or its own way of consuming ecosystem services, which is distinct from that of
- 34 the mining economy in which Lihirians also participate, or the subsistence economy
- 35 through which individual households organise the satisfaction of their daily needs.

- 36 **Plate 4:** Preparations for a feast on Masahet island. [INSERT]

- 37 While a large-scale mining operation on a small island is bound to have a direct physical
- 38 impact on local ecosystems, the injection of large amounts of mineral wealth into the
- 39 subsistence and ceremonial economies of Lihir has an indirect impact on local ecosystems
- 40 which is harder to evaluate and measure. The mining company has understandably
- 41 focused its own process of data collection on the direct physical impact of its operations,
- 42 which is also the focus of attention for environmentalists who maintain a watching brief
- 43 over the large-scale mining industry. However, local community engagement in
- 44 discussion of this issue can only lead to debate about the size of the compensation
- 45 package which community leaders are constantly renegotiating with the company. A
- 46 debate about 'custom' is more likely to engage the community in an assessment of the

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- 1 long-term capacity of local ecosystems, with or without the presence of the mine, to
- 2 supply the needs of a rapidly growing population.

• 3 **3 Delineation and Extent of Local Ecosystems**

• 4 **3.1 The Geophysical Landscape**

- 5 The island of Niolam has been formed around five extinct volcanoes, and the gold mine is
- 6 located within the caldera formed by the youngest of these volcanoes (Hughes and
- 7 Sullivan 1988). Aside from the gold which formed within this melting pot, the legacy of
- 8 past volcanic activity is a mountainous terrain, with dome-shaped peaks and razor-backed
- 9 ridges separated by deep gullies. The four smaller islands of the group are all raised coral
- 10 shelves, and the three inhabited islands all have flat tops with sheer sides and a narrow
- 11 coastal strip. The eastern side of Niolam is subject to gradual tectonic uplift which is
- 12 causing gradual inundation of the western coastline (Sullivan 1990).

- 13 The coastal geomorphology of the whole island group is mainly characterised by cliffs,
- 14 raised reef platforms, and occasional strips of sandy beach. More extensive coral reefs
- 15 have developed off the eastern and northeastern headlands of Niolam and on the northern
- 16 side of Malie, but are generally limited in their occurrence by the steep descent of the sea
- 17 bed around each of the islands in the group. This means that the marine component of
- 18 Lihir's coastal zone occupies a much smaller area than the terrestrial component. Aside
- 19 from a few sandy bays or estuaries on Niolam, the inter-tidal zone is dominated by raised
- 20 reef flats or platforms, about 20-50 metres wide in most places, whose seaward edges
- 21 have slopes that vary from about 30 to 80 degrees. The total area of sub-tidal reef slope
- 22 to a depth of 20 metres around the islands of Niolam and Malie is approximately 200
- 23 hectares (Brewer et al. 2003), so the area which reaches to a depth of 10 metres below the
- 24 low tide mark is less than 100 hectares.

- 25 **Plate 5:** Inter-tidal platform on Masahet island. [INSERT]

- 26 **Plate 6:** Coral formation on the Western side of Niolam. [INSERT]

- 27 The PNG Resource Information System distinguishes two Resource Mapping Units
- 28 within the Lihir island group. One of these covers the whole of Ihot and a fairly narrow
- 29 coastal fringe around most of Niolam, while the other covers the mountainous interior of
- 30 the main island and a portion of the northwestern coastline distinguished by steep cliff
- 31 formations and the absence of even the narrowest coastal plain (see Figure 2).

- 32 **Figure 2:** Resource Mapping Units in the Lihir island group. [INSERT]

- 33 There is little evidence of seasonal variation in the pattern of rainfall, although the period
- 34 of northwesterly winds from December to April tends to be slightly wetter than the rest of
- 35 the year. Although there may be one day a year, on average, when rainfall exceeds
- 36 100mm, the rate of runoff from all the islands is very high, so the excess water normally
- 37 reaches the sea without causing major floods or landslides. There are no lakes or ponds
- 38 of any size on any of the islands, and only two rivers of any size on Niolam.

• 39 **3.2 Indigenous Settlement Patterns**

- 40 National census data show that the resident population of Lihir in 1980, before discovery
- 41 of the gold deposit, was 5505, nearly all of whom were indigenous Lihirians (Filer and

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- 1 Jackson 1989:31). Census data from the colonial period suggest that the annual rate of
- 2 indigenous population growth was about 1 percent between 1940 and 1960, and about 2
- 3 percent between 1960 and 1980 (ibid:30). In 1980, the resident population of Niolam was
- 4 3773, with a crude density of 18.5/km², while the resident population of Ihot was 1732,
- 5 with a crude density of 99.5/km².

- 6 Nearly all of the villages and hamlets of Lihir are concentrated in the ‘coastal’ Resource
- 7 Mapping Unit (see Figure 2), and most houses are located within two hundred metres of
- 8 the shoreline. Some Lihirians say that most or all of the people of Niolam used to live in
- 9 the mountainous interior of the island in the pre-colonial period, because they lived in
- 10 fear of seaborne headhunting raids by the people of Ihot. However, a map drawn by a
- 11 German scientist in 1908, shortly after the effective imposition of colonial rule, shows
- 12 numerous coastal settlements around the island, some of which still bear the same names
- 13 today (Filer and Jackson 1989:25-26).

- 14 Those settlements which were located inland seem to have been finally abandoned after
- 15 the Second World War, when the Australian colonial administration encouraged the
- 16 people to congregate in large coastal villages, the sites of which are still remembered as
- 17 ‘camps’. The names of these ‘camps’ then became the official titles of the 27 census
- 18 units into which the population was divided in the late colonial period. Although these
- 19 ‘villages’ still retain their distinctive political identities, most of them now consist of a
- 20 string of hamlets stretched at intervals along the coast. A survey conducted in 1990
- 21 identified more than 400 separate hamlets, most of which were separated from
- 22 neighbouring hamlets or the surrounding vegetation by walls constructed out of slabs of
- 23 coral limestone. This material is so abundant on the small islands of Ihot that walls have
- 24 also been built to separate clan territories or individual garden plots.

- 25 A survey conducted by the mining company found that 2700 hectares of customary land
- 26 over which it secured leases for the development of the mine and associated infrastructure
- 27 was divided into 140 named blocks or parcels, each of which was owned and used by a
- 28 distinctive group of people. While this suggests that the ‘typical’ parcel is just under 20
- 29 hectares in size, the largest block in the survey was more than 200 hectares, so the range
- 30 of variation is very high. The maps produced as part of this survey suggest that the larger
- 31 parcels are those which are located at some distance from a place of current human
- 32 settlement or those with a lower ratio of ecosystem services to land area. Some Lihirians
- 33 maintain that each block of customary land belongs to one or other of the six matrilineal
- 34 clans into which their society is divided. However, the surveys undertaken by the
- 35 company paint a far more complex picture of land rights and group identities, in which
- 36 the pivotal figures are the living owners of those parcels (about 360 in the whole of Lihir)
- 37 which are recognised as places where a men’s house has been or can be built.

• 38 3.3 The Biological Landscape

- 39 The vegetation communities of Lihir can be assigned to one of three altitudinal zones.
- 40 The zone which reaches to about 200 metres above sea level, covering nearly all of Ihot
- 41 and more than 50 percent of Niolam, is a zone of fairly intensive cultivation and forest
- 42 management, while the high mountain slopes of Niolam, at altitudes above 400 metres
- 43 (about 16% of the island’s surface area), are covered by primary forest which shows
- 44 virtually no evidence of human disturbance. The intermediate zone, between 200 and 400
- 45 metres, has been classified as ‘cultivated land’ on the basis of aerial photography from the
- 46 late colonial period (Saunders 1993a) because of the presence of numerous fruit and nut

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- 1 trees (e.g. *Canarium* spp., *Artocarpus* spp.), as well as the occasional swidden garden.
- 2 This pattern was still evident in the 1980s (Filer and Jackson 1989:35).

- 3 **Plate 7:** Coconuts and bush fallows in the lowest altitudinal zone of Niolam island. [INSERT]

- 4 From data collected in 1995, the PNG Land Management Group distinguishes the
- 5 indigenous food-cropping system of Niolam from that of the smaller islands primarily by
- 6 reference to the length of the fallow period (see Figure 3). This clearly reflects the higher
- 7 density of population and the relative shortage of cultivable land on the smaller islands of
- 8 Ihot. In the Niolam system (which is also found in some neighbouring island groups), the
- 9 most important crops are short yam (*Dioscorea esculenta*) and sweet potato, followed by
- 10 long yam (*Dioscorea alata*), cassava, banana and taro. In the Ihot system (which is
- 11 unique to Lihir), sweet potato, cassava and both types of yam are of equal importance. In
- 12 both systems, there is a distinction between those gardens in which a planting of yams
- 13 may be followed by a planting of other root crops, and those in which two plantings of
- 14 sweet potato and/or cassava are made before fallow (Hide et al. 1996). Plantings of sweet
- 15 potato and cassava seem to have been expanding at the expense of taro since the
- 16 beginning of the colonial period (Filer and Jackson 1989:36), which is no doubt related to
- 17 the fact that these are more productive species that can be grown on poorer soils. A
- 18 typically wide range of vegetables, fruits and nuts are interplanted with the root crops,
- 19 and the tree crops then become a significant component of the fallow vegetation in both
- 20 systems. In the Niolam system, bamboo (*Bambusa vulgaris*) is also a preferred
- 21 component of the fallow vegetation, because bamboo poles are used to stake the yam
- 22 vines and to build the fences which keep pigs out of the gardens. On the small islands of
- 23 Ihot, where bamboo is in short supply, yams are commonly staked with *Hibiscus tiliaceus*,
- 24 which then becomes a significant part of the woody regrowth fallow.

- 25 **Figure 3:** Food-cropping systems in the Lihir island group. [INSERT]

- 26 In 1985, a survey of 19 food gardens on Niolam found that these ranged in size from 900
- 27 to 2800 m², while 8 food gardens on Masahet were between 440 to 700 m² in extent (Filer
- 28 and Jackson 1989:35,39). Despite this variation in garden size, the authors estimated that
- 29 each Lihirian accounted for roughly 600 m² of land cleared for swidden gardens each year
- 30 (ibid:36). In 1992, a survey of 16 households in three Niolam villages and 6 households
- 31 in one Masahet village (Bonnell 1992) found that 86 people on Niolam accounted for 38
- 32 gardens with a combined area of 5.436 hectares (632 m² per person), while 50 people on
- 33 Masahet accounted for 50 gardens with a combined area of 2.405 hectares (481 m² per
- 34 person). These figures suggest that the total area of land cleared for new swidden gardens
- 35 in the decade preceding development of the mine would have been 250-300 hectares per
- 36 annum (less than 1.5% of the total surface area) on Niolam, and 85-100 hectares per
- 37 annum (or 5-6% of the total surface area) on the smaller islands of Ihot.

- 38 **Plate 8:** New garden clearance on the western side of Niolam. [INSERT]

- 39 **Plate 9:** New garden clearance on Malie island (with megapode nesting hole). [INSERT]

- 40 There is a great deal of local variation in the frequency with which cultivable land is
- 41 actually cleared to make new swidden gardens, and some areas are more or less
- 42 permanently excluded from the food-cropping system. The areas of human settlement
- 43 tend to be located on sandy soils which are not suitable for swidden cultivation. The
- 44 settlements are typically interspersed and surrounded by 'orchards' of coconut and areca

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- 1 palms and other tree crops. Several blocks of land on Niolam, with a combined area of
- 2 roughly 1000 hectares, were alienated from customary ownership by the colonial
- 3 administration, and at least a third of this area had been converted into coconut
- 4 plantations by the end of the colonial period. Local villagers in the south of the main
- 5 island had also developed their own cash crop plantations by the end of the 1970s (see
- 6 Figure 3). There are small clumps of sago palms scattered around Niolam, especially in
- 7 the coastal reaches of streams on the western side of the island, while the most extensive
- 8 single area of sago swamp (more than 50 hectares) is located in the northeastern corner of
- 9 the island, and has traditionally supplied the needs of Malie and Masahet people, who
- 10 have no sago on their islands. In Luise Caldera, which is now the site of the gold mine,
- 11 extensive thickets of bamboo (about 40 hectares altogether) may have developed in places
- 12 because the high sulphur content and ground temperature of the volcanic soils inhibited
- 13 the practice of swidden farming.

- 14 On the northern coralline shelf of Niolam, there are some pure stands of *Calophyllum* -- a
- 15 tree which is normally only found in the mixed lowland rainforests of Melanesia (Filer
- 16 and Jackson 1989:25). These are likely to have developed on land which was once
- 17 cultivated quite intensively, but then abandoned (Bayliss-Smith et al. 2003). In the same
- 18 vicinity, there are several areas of land (more than 300 hectares altogether) at elevations
- 19 between 50 and 150m, which are covered in 'kunai' grass (*Imperator cylindrica*) and a
- 20 species of pandanus (*Pandanus pyriformis*). The Lihirian language has a distinct name
- 21 for this vegetation community (*bap*), and the land which supports it seems to have been
- 22 degraded by previous cultivation to the point at which it will no longer support any other
- 23 kind of secondary regrowth. This type of scrubland is also found in smaller patches on
- 24 the small islands of Ihot, but these patches are not big enough to be distinguished in aerial
- 25 photographs. Other areas of degraded land on the small islands, especially on Malie and
- 26 Masahet, are now covered by a fern (*Dicranopteris linearis*) which Lihirians call *malo*.
- 27 This species has rhizomes which make it very difficult for local farmers to bring the
- 28 land back into cultivation again.

- 29 **Plate 10:** Ferns (*malo*) on Masahet island. [INSERT]

- 30 Forest fallows constitute the primary habitat of Lihir's very large herd of domesticated
- 31 pigs. On Niolam, pigs were (and generally still are) allowed to forage through these areas
- 32 instead of being penned in their own enclosures, and that explains why areas of human
- 33 settlement and swidden gardens have to be surrounded by walls and fences. On the
- 34 smaller islands, the higher density of the human population is associated with a lower
- 35 ratio of pigs to people and a more concerted effort to separate the pig habitat from the
- 36 areas of settlement and active cultivation. On the island of Masahet, for example, a
- 37 combination of stone walls and bamboo fences was built in order to divide the whole
- 38 island into three concentric zones, and thus confine the pigs to the area of secondary
- 39 forest between the coastal zone of human settlement and the interior plateau where short-
- 40 fallow swidden cultivation predominates. Where stone walls have been built to protect
- 41 gardening areas in the Ihot food-cropping system, individual plots can be cultivated for
- 42 more than two years without the risk of pigs breaking through rotting fences (Filer and
- 43 Jackson 1989:39-40).

- 44 Most of the shoreline of all the islands in the group is occupied by the common strand
- 45 formation plants of PNG (e.g. *Hibiscus tiliaceus*, *Calophyllum inophyllum*, *Barringtonia*
- 46 *asiatica*). Mangroves are only found on the western side of Niolam. The inter-tidal reef
- 47 platforms are typically covered in a carpet of algal turf and/or short macro-algae. On

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- 1 some of the reef platforms which trap water after the tide falls, there are significant areas
- 2 of seagrass (including *Thalassia* sp.). Another type of seagrass (*Enhalus* sp.) is found
- 3 sub-tidally in bays and areas dominated by sediment. The bottom cover on the shallow
- 4 sub-tidal reef slope is dominated by scleractinean (stony) reef-building coral species.

• 5 **3.4 Landscape Impacts of Mine Development**

- 6 The total area leased by the national government to the mining company is 2479 hectares.
- 7 This includes the whole of Luise Caldera and a portion of Luise Harbour within the
- 8 Special Mining Lease (1738 hectares), and the whole of the area formerly occupied by the
- 9 largest commercial coconut plantation on Niolam, which is now the site of the mining
- 10 township. The SML includes the mine pits, stockpiles, and waste dumps, along with the
- 11 processing plant and docking facilities. Three other leases in the northeastern corner of
- 12 Niolam cover the town site, the new high school, a golf course, an airport, two stone
- 13 quarries, a dam (on one of the island's two main rivers), and a reservoir. Under the terms
- 14 of its development agreements with the government and local community leaders, the
- 15 mining company has also helped to construct and maintain an all-weather ring road
- 16 connecting the mine, the town and the airport with all the coastal villages of Niolam, and
- 17 has blasted a number of passages through the raised reef platforms surrounding the
- 18 smaller islands of Ihot in order to facilitate motor boat access.

- 19 About 80 families were moved out of the SML at the time of mine construction, and most
- 20 of them moved into modern relocation houses built by the mining company (Filer et al.
- 21 2000:72). The company has also funded a 'Village Development Scheme', which was
- 22 initially for the benefit of other households in northeastern Niolam and on the small island
- 23 of Malie who count as residents of the 'mine-affected area', but which has more recently
- 24 been extended to other areas (Macintyre and Foale 2003). This scheme has mainly been
- 25 used to pay for the construction of modern housing, but also for the installation of
- 26 reticulated power and water supplies, and the provision of sanitation and waste disposal
- 27 facilities. The mining company has also upgraded village water supplies in a number of
- 28 other villages outside the 'mine-affected area'.

- 29 **Plate 11:** House constructed by the mining company under the Village Development Scheme.
- 30 [INSERT]

- 31 The mining company has not directly modified the whole of the landscape enclosed
- 32 within its various leases. Some of the villagers who were relocated out of the SML have
- 33 since moved back to their old village, while renting their relocation houses to other
- 34 families. More than 70% of the SML, including the steep slopes of the caldera wall, is
- 35 still forested, and more than 40% of the company's other leases areas are covered by a
- 36 combination of swidden gardens and forest fallows. A single block of almost 50 hectares
- 37 within the former plantation lease has recently been cleared by Malie islanders in order to
- 38 make new swidden gardens (Macintyre and Foale 2003).

- 39 **Plate 12:** Aerial photograph from 1998, showing parts of the mining companies Londolovit leases
- 40 (bounded in green), and the area which has since been cleared for cultivation by Malie islanders
- 41 (bounded in red). [INSERT]

4 Ecosystem Services and Human Well-Being

4.1 Classification and Measurement of Coastal Ecosystem Services

The gold produced by the mining company is a service which one small part of Niolam island provides to the rest of the world. Insofar as the people of Lihir receive a share of the wealth produced by this activity, the gold also counts as a material benefit which they derive from one part of their territorial domain. But what about the services which they derived from this domain before the mine was developed? Do they still derive the same range of services from those local biological communities which have, to a greater or lesser degree, survived the construction of the mine and its associated infrastructure? To what extent, and in what way, are these services shared with the mining company, or with individual workers who have been directly engaged in the construction and operation of the mine? Has there been a significant change in the relative value or availability of different types of ecosystem service? And what attempts have been made to measure this kind of change?

4.1.1 Local Food Supplies

Before the development of the mine, Lihirians derived the greater part of their food supply from the mixture of swidden gardens, forest fallows, and orchards which constitute the 'zone of cultivation' in which they still practice a form of agroforestry that is typical of coastal Melanesia. The supply of food from the mountainous forested interior of Niolam (above 200m) was very limited in the period preceding development of the mine, and is even more limited now, because the local inhabitants rarely venture more than a few kilometres inland from their coastal settlements unless they are involved in cultivating the occasional yam garden on some of the steeper hill slopes. The hunting of wild animals and birds has never been a major source of protein by comparison with the meat derived from pigs and chickens, and most of this hunting activity has been confined to the zone of cultivation. Lihirians have not traditionally used bows and arrows, and there were only two or three shotguns on the whole of Niolam in the period before the start of mine construction (Menzies 1989).

Despite the present concentration of the population in settlements on or near the shoreline, fishing has not been a major source of protein in the typical Lihirian diet. A survey of six villages undertaken before the start of mine construction found that individuals were consuming an average of 16.86 (± 7.15) grams of whole fish per day, and the actual protein content of that fish was calculated as 3.71 (± 1.17) grams per day, which represents about 10% of the recommended daily protein requirement of a moderately active adult (NSR 1989a). Surveys of fishing activity and food intake undertaken since the start of mining operations (Foale 1998; Brewer et al. 2003) do not allow for a direct comparison with these earlier figures, but they show that the average Lihirian household now consumes fresh fish or marine invertebrates once a week, and this represents a somewhat higher level of consumption than the one found in the earlier survey, even though the average household can now afford to purchase larger quantities of canned mackerel and other imported protein. Imports from neighbouring island groups explain part of the increased consumption of fresh fish and invertebrates (especially crayfish), but the increase in local cash incomes from mining has also increased the availability and affordability of modern fishing gear (steel hooks, monofilament line, nylon nets, fibreglass boats and outboard motors) for much of the population.

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- 1 The PNG Land Management Group has reanalysed data collected by the National
- 2 Nutrition Survey of 1982/83 in terms of the distinctions now drawn between the
- 3 indigenous food-cropping systems of PNG. The original survey asked a sample of
- 4 families what they had eaten on the previous day. Table 1 shows the results for the two
- 5 food-cropping systems found in the Lihir island group, but it should be borne in mind that
- 6 the 'Niolam' system is not exclusive to Lihir, and the sample therefore includes families
- 7 from other island groups in New Ireland Province. (The 'Niolam' sample comprised 78
- 8 families from 7 villages; the Ihot sample comprised 31 families from 2 villages.) All food
- 9 types shown in this table would have been locally produced except for rice.

- 10 **Table 1:** Proportion of families consuming different types of food in different food-cropping
- 11 systems, 1982.

| SYSTEM | Coconut | Sweet potato | Yam | Cassava | Banana | Taro (2 types) | Rice |
|----------|---------|--------------|-----|---------|--------|----------------|------|
| 'Niolam' | 62% | 58% | 46% | 28% | 17% | 9% | 18% |
| 'Ihot' | 81% | 94% | 58% | 39% | 6% | 0% | 27% |

- 12 Source: Hide et al. 1996:66,77.

- 13 These figures suggest that coconuts grown on customary land were more important as a
- 14 source of food than as a source of cash, especially on the small islands of Ihot, where the
- 15 very limited availability of fresh water meant that villagers were obliged to quench their
- 16 thirst with coconut milk during periods of drought or dry weather.

- 17 While the mix of garden crops is still much the same as it was before the injection of
- 18 mineral wealth into the local economy, imports of rice and flour have since modified
- 19 demand for some of the locally cultivated root crops. Yams are an exception to this rule,
- 20 because they are one of the basic ingredients of the ceremonial economy, and the demand
- 21 for yams has grown with the intensification of the ceremonial feasting cycle. Local
- 22 garden surveys have indicated a distinction between the larger yam gardens linked to the
- 23 ceremonial economy and the smaller mixed-crop gardens linked to the subsistence
- 24 economy (Bonnell 1992), so this distinction should still be evident in areas where it is
- 25 possible to secure good yam yields.

- 26 Pigs have also retained their status in the ceremonial economy of Lihir, as well as being
- 27 the main source of animal protein in the traditional food supply. Coconuts have always
- 28 been significant as the major source of food for the local pig population, as well as the
- 29 local human population, and surplus coconuts which might once have been converted into
- 30 copra are now fed to pigs instead of being sold for cash.

- 31 The catering company which feeds the mining workforce bought just over K40,000 worth
- 32 of locally grown fruit and vegetables in 2002, which represented less than 0.5% of its
- 33 total food purchases, the rest being imported (Macintyre and Foale 2003). The value of
- 34 locally grown areca (betel) nut sold to outsiders employed in the mining economy may
- 35 well exceed that of the food sold to the catering company, but there is no data on the
- 36 volume or value of such sales, and it is not clear how much of the betel nut circulating on
- 37 the islands has been imported and sold by the immigrant traders who are not formally
- 38 employed in the mining economy. Lihirians also sell some fresh food to outsiders in the
- 39 local markets, but the volume and value of these transactions is also unknown.

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• 1 4.1.2 *Other Ecosystem Services*

- 2 The zone of cultivation is the source of nearly all of the medicinal plants traditionally
- 3 used by Lihirians, and many of these are actively cultivated. There is no empirical data
- 4 on changes in the rate of use of traditional medicines which might be explained by the
- 5 increased availability of modern drugs and medical treatment in the mining economy, but
- 6 it appears that traditional medicines are still commonly and widely used in the community.
- 7 Lime, which is made from coral, is a central ingredient in many traditional medicines (as
- 8 well as being chewed with betel nut). Most often it is combined with various medicinal
- 9 plants to generate a paste that is usually applied as a topical remedy, even for alimentary
- 10 diseases, colds and pneumonia. It is also used extensively in sorcery, often by itself.
- 11 Lime was traditionally made from local coral, but since the start of mining operations,
- 12 much of it has been imported from elsewhere and purchased in the local markets.

- 13 Traditional uses of some of the raw materials derived from local ecosystems were already
- 14 declining before the development of the mining economy, and have continued to decline
- 15 with the substitution of imported goods. This would be true of the coconut or black palm
- 16 trunks traditionally used to make fighting spears, the logs formerly used to make dugout
- 17 canoes, or the bamboo formerly used to make a wide variety of containers and
- 18 implements. But the overall demand for hardwoods and bamboo has been sustained by
- 19 their other uses. Traditional building materials are still in demand, despite the large
- 20 quantities of imported modern housing materials that have now been distributed around
- 21 the island group. Local hardwoods (including mangroves) are still used to make house-
- 22 posts and rafters; bamboo to make walls, floors, benches and fences; sago and pandanus
- 23 leaves to make thatch; and vines to tie the various components together. Coconut and
- 24 pandanus leaves are used to make mats, while coconut leaves are also used to make the
- 25 very large baskets in which Lihirian men carry their personal effects. Lihirians still use a
- 26 variety of flowers, leaves, and roots, along with local lime and clay, to decorate their
- 27 bodies for ceremonial purposes, but animal products (such as fur and feathers) are
- 28 generally not used in this way. Firewood is mostly obtained from forest fallows, and still
- 29 accounts for most of the energy used in cooking.

- 30 Drinking water has traditionally been obtained from creeks and springs, or by means of
- 31 various artificial techniques for the collection and storage of rainwater (NSR 1989b). In
- 32 areas with limited supplies of fresh water – especially on the small islands of Ihot –
- 33 villagers traditionally bathed in the sea. During periods of drought, coconut milk became
- 34 an important substitute for drinking water. While the mining company and its employees
- 35 now consume a significant portion of the fresh water available in the mine-affected area
- 36 of northeastern Niolam, the installation of new techniques for extraction and storage have
- 37 maintained the overall level of supply for local villagers, and have increased it quite
- 38 substantially on the smaller islands. Where wells have been dug, the movement of the
- 39 water level is influenced primarily by tidal levels rather than local consumption.

- 40 The volcanic springs which were formerly a characteristic feature of the area now
- 41 occupied by the mining operation could be regarded as a miniature ecosystem in their
- 42 own right. This ecosystem used to supply local villagers with a distinctive set of services:
- 43 the eggs laid in the warm ground by a type of scrubfowl (*Megapodus freycinet eremita*)
- 44 (Burrows 1989); the red clay used as medicine or for personal decoration; and the hot
- 45 spring water itself, which could be used for cooking and was also thought to have
- 46 medicinal properties (Sullivan and Hughes 1989). This ecosystem now supplies the
- 47 mining company with geothermal energy which is converted into electricity, and accounts

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- 1 for an increasing share of the company's overall power supply (the rest being derived
- 2 from diesel generators).
- 3 **Plate 13:** Geothermal energy harnessed as part of the mine dewatering process. [INSERT]
- 4 The spriritual or cultural values which Lihirians attach to the local landscape are
- 5 primarily articulated through the ceremonial economy and the practice of magic. This
- 6 point can be appreciated through the contrast between the amount of labour devoted to the
- 7 beautification of local cemeteries (which are part of the ceremonial economy) and the use
- 8 of local beaches as toilets and rubbish dumps. Although the devaluation of beaches may
- 9 seem odd to European eyes, Lihirians have a rich body of indigenous knowledge relating
- 10 to the many kinds of spiritual beings thought to inhabit local ecosystems. Adherents of
- 11 the so-called 'betelnut' cult are said to be able to imbibe medicinal and magical
- 12 knowledge of various plants in the forest by ingesting parts of those plants along with
- 13 betelnut, usually while in a hallucinatory state. The attachment of spiritual values to coral
- 14 reefs can also be inferred from the prohibitions imposed on fishing activities as part of the
- 15 ceremonial economy. When a 'big man' starts to lose his teeth, one or more of these
- 16 teeth is often thrown out onto the reef, and fishing on that part of the reef may then be
- 17 prohibited for a period of at least three months (and sometimes several years). When the
- 18 prohibition is lifted, fish are harvested and consumed at a feast.
- 19 **Plate 14:** Village cemetery adjacent to the mine site. [INSERT]
- 20 **Plate 15:** Domestic rubbish on beach adjacent to the mine site. [INSERT]
- 21 While hunting is not significant as a source of protein in the Lihirian diet, or even as a
- 22 source of raw materials such as bones or feathers, the mining economy has supplied local
- 23 children with old inner tubes which are used in the manufacture of slingshots (Macintyre
- 24 and Foale 2004a). These have reduced the population of birds and bats, especially in the
- 25 'mine-affected area'. This kind of 'sporting' activity can also be regarded as the
- 26 consumption of an ecosystem service, even if it does not qualify as part of a cultural or
- 27 spiritual value system.
- 28 **Plate 16:** Boys hunting parrots with slingshots. [INSERT]
- 29 Insofar as Lihirians possess an indigenous knowledge of what are here called the 'control
- 30 functions' of local ecosystems, this knowledge is primarily focused on the local food-
- 31 cropping system, and especially the maintenance of soil fertility. For example, the use of
- 32 *Hibiscus tiliaceus* to make yam stakes on the smaller islands is apparently based on a
- 33 recognition of the fact that this species is an excellent nutrient pump within a short-fallow
- 34 rotation, because it grows rapidly and has deep roots which can transfer subsurface
- 35 nutrients to the surface in the form of rotting leaves (as well as being a good source of
- 36 firewood).
- 37 **4.2 Classification and Measurement of External Transactions**
- 38 Between 1983 and 1997, the local mining economy replaced a local plantation economy
- 39 of the kind that was formerly typical of coastal Melanesia. During the late colonial period
- 40 and the first decade of the post-colonial period, Lihir was exporting 400-500 tonnes of
- 41 copra per annum, and local smallholders contributed more than half this total during the
- 42 1970s. By 1988, smallholders were no longer cutting copra, and the mining company,
- 43 which had taken over the management of the largest commercial plantation (now the site

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- 1 of the mining town), was exporting a token quantity of 7 tonnes a month (Filer and
- 2 Jackson 1989:84). During the 1970s, some of the smallholders in southern Niolam had
- 3 planted cacao as a second cash crop, and they were exporting 20-30 tonnes of cocoa per
- 4 annum in the 1980s, but this activity also ground to a halt with the development of the
- 5 mine.

- 6 In 1987, the average Lihirian villager had an estimated annual cash income of about K100
- 7 (then about US\$100), 40% of which was already derived from the process of mineral
- 8 exploration (ibid:91), so imported goods were still rare luxuries for the vast majority of
- 9 villagers who did not have a regular job with the mining company, the government, or the
- 10 Catholic mission. A survey of village assets in 1985 counted a total of 7 trucks or tractors,
- 11 most of which belonged to the owners of the 6 cocoa fermentaries, and 56 outboard
- 12 motors attached to speedboats or dugout canoes, many of which were not in working
- 13 order (ibid:93). There were 43 village trade stores selling a small range of imported food
- 14 items and other consumer goods, and a few 'business groups' which specialised in the
- 15 sale of imported fuel. Their combined annual turnover was probably less than the
- 16 K200,000 spent in the store run by the Catholic mission (which also ran the cargo vessel
- 17 carrying most of the island's imports and exports).

- 18 By 2001 the Lihir gold mine accounted for more than 10% of PNG's total export earnings,
- 19 and the mining company or its contractors had obviously imported a huge quantity and
- 20 variety of materials to construct and maintain the mine itself and all the associated
- 21 infrastructure for which it is responsible. About 2000 people are currently employed by
- 22 the mining company or its contractors, and another 500 are employed in the local public
- 23 sector. About 40% of these employees are Lihirians, which means that roughly 20% of
- 24 the 'adult' Lihirian population (over 15 years of age) are in formal employment. The
- 25 1200 outsiders employed in the mining economy do not play a significant role in Lihir's
- 26 balance of trade, because very little of what they purchase locally is taken out of the
- 27 islands, and very little of what they import in their luggage is sold to anyone else.

- 28 Cash incomes to the Lihirian household economy from wages and mining royalties now
- 29 amount to roughly K1000 per capita per annum for a population which has doubled in
- 30 size since 1987, but devaluation and inflation mean that this is probably worth less than
- 31 K250 in 1987 prices. Average cash incomes were higher during the construction phase,
- 32 from 1995 to 1997, when K14 million was paid out in compensation to local landowners,
- 33 but the current level of income probably represents the peak of local earnings during the
- 34 mine's operational phase. Cash incomes are very unequally distributed at their point of
- 35 entry to the Lihirian household economy, and have been so since the gold deposit was
- 36 first discovered, but there is very little evidence about the redistribution of these incomes
- 37 between Lihirian households or about the proportions in which they are spent on imported
- 38 goods and services.

- 39 A major proportion of cash incomes to the household economy is spent on manufactured
- 40 commodities, some of which (like food or modern building materials) are substitutes for
- 41 local ecosystem services, while others (like modern fishing gear) change the way in
- 42 which those services are exploited or consumed. As Lihirian cash incomes have risen in
- 43 comparison with those of villagers in other parts of New Ireland Province, there has also
- 44 been an increase in the proportion of 'traditional' ecosystem services (such as lime)
- 45 which Lihirians purchase from other parts of the province, and also in the quantity of
- 46 items (especially pigs) which are imported for use in the ceremonial economy, rather than
- 47 the household economy. This last kind of trade predates the local plantation economy, as

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- 1 well as the mining economy, but has now become a mechanism by which Lihirians
- 2 redistribute a portion of the surplus income earned from the mining economy in order to
- 3 fund the expansion of their ceremonial economy.

- 4 The shell money which still plays an important role in the ceremonial economy is mostly
- 5 manufactured on the small islands of Ihot with raw material purchased from other parts of
- 6 New Ireland Province. The local manufacture of shell money is of fairly recent origin,
- 7 having replaced an older system of barter trade in which shell money entered the islands
- 8 from the west or northwest in exchange for pigs and other goods which were either
- 9 produced within the islands or imported from other communities to the south or southeast
- 10 of the Lihir island group (Filer and Jackson 1989:64). Several links in this older trading
- 11 chain seem to have been broken after the Second World War, but the exchange of Ihot
- 12 shell money for Niolam pigs continued, and Lihirians were still importing several dozen
- 13 pigs a year from the mainland of New Ireland in the 1980s, for which they either paid
- 14 with shell money or with cash (ibid:65,98). Imports of pigs and shells have risen
- 15 dramatically with the rise in cash incomes derived from the mining operation, so the
- 16 ceremonial economy continues to flourish on the back of an expanding cash economy
- 17 (Macintyre and Foale 2003).

- 18 The imbalance of trade between Lihir and the rest of the world now means that gold
- 19 accounts for almost 100% of the value of all Lihirian exports. No cash crops are
- 20 currently being exported (although one enterprising farmer has recently begun to plant a
- 21 vanilla crop). A few people are engaged in the occasional harvesting of beche-de-mer
- 22 and trochus shells, but they have to take their wares to market by themselves, because no
- 23 commercial buyers visit the islands. Hardly any of the local products purchased by
- 24 outsiders employed in the mining economy are taken out of the islands, and other visitors
- 25 to the islands are primarily interested in gaining access to a share of Lihir's golden
- 26 windfall rather than buying anything from Lihirian households.

• 27 **4.3 Classification and Measurement of External Interactions**

- 28 By far the most significant of the alien life forms introduced to Lihir during the colonial
- 29 period were the diseases introduced as a result of contact with Europeans. As in other
- 30 parts of the Bismarck Archipelago, government officials were concerned by the apparent
- 31 decline of the 'native' population during the early colonial period as a result of the impact
- 32 of venereal diseases on the fertility rate, but the decline was not as marked in Lihir as it
- 33 was in other parts of New Ireland Province (Scragg 1957). Tuberculosis, leprosy and
- 34 influenza also had a significant impact: 21 cases of TB and 13 of leprosy were under
- 35 treatment in 1985, most of them in the southern part of Niolam (Filer and Jackson
- 36 1989:158).

- 37 Like other groups of small islands in PNG, Lihir was protected from the invasion of new
- 38 plants and animals by its relative isolation from the rest of the world. Japanese soldiers
- 39 are said to have been responsible for the introduction of cane toads (*Bufo marinus*) during
- 40 World War II, but even after discovery of the gold deposit, there was no clear evidence of
- 41 the arrival of the Black Rat (*Rattus rattus*), which had caused a lot of damage to cocoa
- 42 plantations in other parts of New Ireland (Menzies 1989), nor is there any evidence of its
- 43 subsequent arrival. The Giant African Snail (*Achatina fulica*) has made an appearance on
- 44 the islands since the start of mine construction, and is a matter of some concern to local
- 45 villagers because of the damage done to their food gardens, although the extent of the
- 46 damage has not been measured (Macintyre and Foale 2004a). The accidental introduction

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- 1 of alien plant species over the past century has been far less significant than the deliberate
- 2 introduction of new cultivars to the local food-cropping systems.

- 3 Although the development of the mining economy has undoubtedly multiplied Lihir's net
- 4 contribution to greenhouse gas emissions, the mining company is only obliged to measure
- 5 emissions of sulphur dioxide and hydrogen sulphide as part of the environmental
- 6 monitoring program approved by the government because of concerns about air quality in
- 7 the vicinity of the processing plant. Some efforts have also been made to monitor the
- 8 extent of local coral bleaching caused by remotely generated carbon dioxide (Rotmann
- 9 2001).

• 10 **4.4 Current Patterns of Human Migration and Circulation**

- 11 Government records indicate that there were upwards of 500 Lihirians who were more or
- 12 less permanently absent from the islands in 1980, while 200 out of 5505 people living on
- 13 the islands had not been born there (Filer and Jackson 1989:30). With the development of
- 14 the mining economy, most of the absentees have returned to the islands along with their
- 15 families, and the number of non-Lihirian immigrants has also increased substantially.
- 16 The national census of 2000 counted 13,077 residents, and internal company records
- 17 indicate that 10,823 of these people were Lihirians, so the number of Lihirian residents
- 18 had more than doubled in 20 years. Some (perhaps half) of the non-Lihirian residents
- 19 would have been outsiders employed directly by the mining company or its contractors,
- 20 while the remainder would have migrated to the islands on their own account. It is
- 21 difficult to calculate these proportions because most of the individuals formally employed
- 22 in the mining economy are 'fly-in/fly-out' commuters who may or may not be resident at
- 23 the moment when a census is taken, and also because Lihirians resist the inclusion of any
- 24 outsiders in the population database maintained by the mining company. In March 2003,
- 25 this database counted 12,454 people as indigenous Lihirians resident on the islands. The
- 26 total number of residents is now thought to have doubled since the mining development
- 27 agreements were signed in 1995.

• 28 **4.5 Biological Diversity and the Cultural Significance of Species**

- 29 No species of fauna or flora has so far been identified as being uniquely endemic to the
- 30 Lihir group of islands, with the possible exception of one species of orchid identified in
- 31 one of the early botanical surveys. At one stage in the planning of the gold mine, there
- 32 was some concern about the status of the local scrubfowl population, because of its
- 33 unusual adaptation to the presence of the volcanic springs in Luise Caldera, but this
- 34 adaptation has also been recorded in other parts of Melanesia, and it does not distinguish
- 35 one subspecies from another (Burrows 1989).

- 36 While the mining company agreed to monitor those parts of the local scrubfowl habitat
- 37 which would not be destroyed by mining operations, it has also taken steps to protect
- 38 leatherback turtle (*Dermochelys coriacea*) nesting grounds within its lease areas from
- 39 local people who would rather kill and eat any turtles they can catch (Macintyre and
- 40 Foale 2004b). The turtles count as a 'flagship' species for the company because they also
- 41 have the same value for conservationists who do not generally approve of large-scale
- 42 mining operations in places like Lihir, but they do not count as a keynote or totemic
- 43 species for Lihirians, because they are not essential to the Lihirian 'way of life', nor do
- 44 they have any other special cultural significance.

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- 1 **Plate 17:** Corporate protection of turtle nesting sites near the mine site. [INSERT]
- 2 Since Lihirians use coconuts for many different purposes, we could certainly say that
- 3 coconuts do count here as a cultural ‘keynote’ species, but Lihirians themselves are more
- 4 inclined to assess the importance of plant or animal species in terms of the role which
- 5 they play in the ceremonial economy or in terms of their uneven distribution and relative
- 6 scarcity in different parts of the island group. By these criteria, pigs, yams, sago, and
- 7 betelnut are more significant than coconuts because of their role in ceremonial feasts,
- 8 while sago and bamboo are more significant because they are fairly plentiful on Niolam,
- 9 but very scarce on the small islands of Ihot. These differential valuations were revealed
- 10 in the extent to which the price demanded of the mining company by way of
- 11 compensation for the destruction of these resources departed from the schedule of prices
- 12 recommended by the national government (Filer and Jackson 1989:35).
- 13 Some species count as totemic species because they have a magical or mythological
- 14 significance which is not directly linked to the feasting cycles which make up the
- 15 ceremonial economy. In some parts of Lihir, people regard cycads as the homes of
- 16 environmental or ‘bush’ spirits (known locally as *tandal*), but this type of spiritual being
- 17 is more generally associated with a specific landscape feature, such as a cave, cliff, rock,
- 18 or tree which is conspicuous by its shape, size or position. These spirits may sometimes
- 19 appear in the form of powerful animals (eagles, sharks, pythons) or other natural
- 20 phenomena (Ramstad n.d.).
- 21 The most important creator spirit in Lihirian folklore is associated with the Palolo worm
- 22 (*Palola viridis*) which is harvested from the sea during its annual spawning season --
- 23 usually the day after the full moon in the months of October or November. This spirit is
- 24 believed to be immensely powerful and quite dangerous, so Lihirians take various
- 25 magical precautions on the morning after they harvest the worms, such as decorating
- 26 small children with one of their most potent medicinal plants (a *Ficus* species) to prevent
- 27 the spirit from stunting their growth. Dolphins, on the other hand, are not thought to be
- 28 dangerous, but they are thought to be descended from human beings who got sick of
- 29 living on land because of the need to replace rotten houses, and for this reason Lihirians
- 30 do not hunt or harm them.
- 31 In some respects, the most peculiar faunal species on Lihir is a type of macropod which
- 32 local people call *we*. If this creature really exists, then it must almost certainly be the
- 33 Northern Pademelon (*Thylogale browni*). According to Flannery (1995:83), this species
- 34 of wallaby was deliberately introduced to New Ireland by human beings about 7000 years
- 35 ago, and was later taken to a number of other islands in the Bismarck Archipelago,
- 36 including Buka and Lihir. Flannery says that it ‘apparently’ became extinct on Lihir
- 37 about 50 years ago, but a number of Lihirians (mostly under the age of 50) have insisted
- 38 on recent sightings. Yet they also speak of it as a type of *tandal*, and some say that it
- 39 comes down to the shore at night to ‘wash it’s balls’ in tide pools after it has accidentally
- 40 stumbled over the spiny vine of a species of wild yam that grows in the forest.
- 41 **4.6 Relationship between Ecosystem Services and Human Well-Being**
- 42 It could be argued that Lihir exemplifies the *lack* of any close relationship between
- 43 ecosystem health and human well-being. The authors of the social impact assessment for
- 44 the gold mine observed that the people of southern Niolam were in generally poorer
- 45 health than those in the rest of Lihir, and were also less likely to take advantage of health

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- 1 services provided by the Catholic mission, despite the fact that they had easier access to
- 2 the mission health centre, and also had higher per capita cash incomes from the sale of
- 3 copra and cocoa. This led them to suggest that people in this area ‘were suffering from a
- 4 type of multiple deprivation that had no obvious economic or environmental explanation’
- 5 (Filer and Jackson 1989:158). The subsequent development of the mining economy has
- 6 apparently led to a very substantial improvement in the health and well-being of the
- 7 whole population of Lihir, including the people of southern Niolam, but this form of
- 8 economic development has not exactly led to an increase in the overall supply of local
- 9 ecosystem services to local consumers.

- 10 The baseline health survey undertaken by the mining company found an average
- 11 malnutrition rate of 4.5% amongst children under 5 years old, which was more than 3
- 12 times the national average at that time (Taufa et al. 1991). But it also found a plausible
- 13 environmental explanation for the phenomenon observed in the social impact assessment,
- 14 by showing a correlation between the incidence of malaria and the distinction between the
- 15 two Resource Mapping Units on the islands (see Figure 2). Malaria was ‘meso-endemic’
- 16 in settlements constructed on limestone soils, and ‘hyper-endemic’ in settlements
- 17 constructed on volcanic soils. The obvious explanation for this difference is the lower
- 18 rate of water retention on the limestone soils, but the variable incidence of malaria –
- 19 considered as an ecosystem *disservice* -- also helps to explain the higher population
- 20 densities on these limestone soils, despite the relative scarcity of the material benefits
- 21 which local people can derive from this type of ecosystem.

- 22 The mining company has instituted a malaria control program in the ‘mine-affected area’
- 23 in order to safeguard the health of its own workforce as well as the local villagers. This
- 24 had a dramatic impact in the first few years of the mining operation, but the disease has
- 25 since made something of a comeback in the village population (see Figure 4).

- 26 **Figure 4:** Distribution of malaria in selected villages of Niolam. [INSERT]

- 27 The incidence of most of the other ‘diseases of poverty’ has also fallen dramatically as a
- 28 result of the increase in local cash incomes and the construction of a new hospital, and the
- 29 distinction formerly observed between the health and well-being of people living in the
- 30 two ‘ecosystems’ labelled as Resource Mapping Units has now been overlaid, or even
- 31 replaced, by a distinction between the health and well-being of people living inside and
- 32 outside the ‘mine-affected area’ which straddles that ecological divide, because the
- 33 people of the mine-affected area have higher per capita cash incomes and easier access to
- 34 the new hospital.

- 35 At the same time, access to mineral wealth is a primary factor in the deterioration of
- 36 several local indicators of human well-being which could be classified as ‘diseases of
- 37 affluence’, like obesity or diabetes, or as signs of social dysfunction, such as alcohol
- 38 abuse and domestic violence, which have been documented in the mining company’s
- 39 social monitoring reports (Maintyre and Foale 2000, 2001, 2003). The relationship
- 40 between these phenomena and the supply of local ecosystem services is almost
- 41 impossible to measure as part of a local ecosystem assessment.

- 42 **4.7 Relationship between Ecosystem Capacity and Human Demand**

- 43 The social impact assessment conducted as part of the environmental planning process for
- 44 the gold mine calculated the extent of population pressure on available gardening land by

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- 1 asking local villagers to estimate the minimum length of the fallow period that would be
- 2 required to maintain the existing food-cropping system and compared this with an
- 3 approximate measure of the amount of land per capita that was actually being cleared for
- 4 swidden cultivation each year (Filer and Jackson 1989:36). The key inference was that
- 5 each Lihirian needed an average of 0.52 hectares of land (including fallow land) to be
- 6 devoted to the indigenous food-cropping system in order to meet his or her need for
- 7 vegetable food in the absence of any imported substitutes. With due allowance made for
- 8 continued population growth and the existence of some areas unsuitable or unavailable
- 9 for swidden gardening, it was predicted that the amount of land required to support the
- 10 population of Malie would be 118% of the gardening land available on the island by 2020,
- 11 while Masahet would just have passed this limit of sustainability by that same date
- 12 (ibid:38). Figure 5 shows that these limits had already been reached or surpassed in 2003,
- 13 mainly because the earlier predictions underestimated the rate of population growth
- 14 throughout the islands.

- 15 **Figure 5:** Land required for gardening as percent of land available in different parts of Lihir,
- 16 1980-2003. [INSERT]

- 17 If we use a simple linear extrapolation to forecast the population in 2012, when open-pit
- 18 mining is predicted to cease, there will be another 5546 people on Lihir, *not including*
- 19 *migrants*. These extra Lihirians will need to have put a minimum of another 28.84 km² of
- 20 land under fallow rotation to feed themselves. Factors that would generate variation
- 21 around this estimate would include: (1) population increase is not linear; (2) the loss of
- 22 gardening knowledge and skills in the meantime, which would decrease gardening
- 23 efficiency, and result in more land being required per person; and (3) a significant
- 24 embrace of intensification techniques such as mulching and/or use of chicken manure,
- 25 which would result in less land being required per person.

- 26 **Plate 18:** Cultivating stony ground on Masahet island. [INSERT]

- 27 We have no actual empirical measure of the proportion of Niolam under bush fallow
- 28 rotation at present, but if we assume that half of Malie's population (292) are making one
- 29 garden per person on Niolam, and a quarter of Masahet's (389) are doing the same, then
- 30 we can assume that at least 52.09 km² (25% of the land area) was under fallow rotation as
- 31 of March 2003. By 2012 this figure will increase to at least 40%. If we use a more
- 32 conservative population extrapolation that assumes the recent very high growth rates
- 33 (6.9% for 1999 and 3.9% for 2003) will decline back to the national average of 2.2% by
- 34 2006, then the population in 2012 will be 15,444 (*not including immigrants, or their*
- 35 *children*), which will theoretically require that 30% of Niolam be under bush fallow
- 36 rotation.

- 37 Those people in northeastern Niolam who have lost land and resources to the mine and its
- 38 associated infrastructure also face a difficult future, because most of the cash
- 39 compensation which they received for this damage has long since been spent. By 1998,
- 40 villagers who had been relocated to make way for the processing plant were already
- 41 complaining about a local shortage of bamboo and coconuts. Although they could still
- 42 afford to purchase such things from other villagers, they were being asked to pay an
- 43 unusually high price because the sellers resented the unequal distribution of mineral
- 44 wealth which favoured the customary owners of the Special Mining Lease (Filer and
- 45 Mandie-Filer 1998).

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- 1 While it could be argued that fish are still an underutilised resource in the Lihirian
- 2 economy, the relatively small area of reef within the traditional domain of the islanders
- 3 means that inshore stocks are unlikely to support a significant increase in pressure over
- 4 current subsistence fishing rates (Brewer et al. 2003). Since traditional fishing techniques
- 5 were mainly applied to the inter-tidal zone and the narrow band of fringing reef which
- 6 surrounds each of the islands in the group, the application of modern technology appears
- 7 to entail an expansion of fishing activity beyond the coastal zone as we have defined it, so
- 8 the apparent increase in domestic consumption of fresh fish and invertebrates does not
- 9 necessarily mean that more food is now being derived from coral reefs or other marine
- 10 ecosystems within the coastal zone. It could even be argued that fish and invertebrate
- 11 populations on the inter-tidal platform have been chronically over-fished, with only the
- 12 occasional increase in density facilitated by the imposition of temporary prohibitions on
- 13 fishing or gleaning as part of the ceremonial economy.

- 14 **Plate 19:** Traditional fishing methods applied on the edge of the inter-tidal platform. [INSERT]

• 15 **4.8 Linkages and Trade-Offs between Ecosystem Services**

- 16 If gold counts as an ecosystem service, then the most important trade-off on Lihir today is
- 17 between the temporary influx of mineral wealth derived from the export of this service
- 18 and the long-term prospect of a growing scarcity of most other ecosystem services as
- 19 local incomes from the mining economy diminish and eventually cease. However, it
- 20 would be wrong to imagine that Lihirians formerly lived in a state of ‘primitive affluence’
- 21 in which trade-offs (or tough choices) were unknown.

- 22 The choice between living on a small island with a shortage of gardening land and living
- 23 on a bigger island with a bigger dose of malaria is one example of a ‘traditional’ trade-off,
- 24 but there is no evidence to suggest that Lihirians actually saw the choice in these terms.
- 25 For those living on the smaller islands of Ihot, whether by choice or by custom, the more
- 26 obvious trade-off has long been the one between the demand for pigs which is generated
- 27 by the ceremonial economy and the need for a daily food intake which is generated by the
- 28 household economy. This trade-off results from the fact that pigs compete with human
- 29 beings for ecosystem services provided by the zone of cultivation.

- 30 A second trade-off emerged with the development of the plantation economy, which
- 31 involved the choice between planting cash crops or food crops in this same zone.
- 32 However, this was not an especially tough choice for the people of southern Niolam,
- 33 where most of the smallholder cash cropping was located, because there was no shortage
- 34 of cultivable land.

- 35 Now that the mining economy has replaced the plantation economy as the primary source
- 36 of local cash incomes, there are multiple trade-offs between the mining economy, the
- 37 household economy and the ceremonial economy, but these trade-offs are difficult or
- 38 impossible to measure.

• 39 **5 Drivers of Ecosystem Change**

• 40 **5.1 Identification and Classification of Key Drivers**

- 41 The mining company and the local community have radically different understandings of
- 42 the drivers of ecosystem change in the Lihir islands. They might perhaps agree on the

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- 1 identification and classification of the key drivers, but there is no agreement about their
- 2 relative significance or their mutual relationship. A scientific assessment of the drivers is
- 3 therefore likely to be challenged by representatives of the local community as a distortion
- 4 or violation of indigenous knowledge, because the practice of 'science' is identified with
- 5 the activities and claims of the company's environmental monitoring program.
- 6 There have been several cases since the start of mine construction in which the company
- 7 has used 'scientific evidence' to dispute compensation claims made by members of the
- 8 local community, but the arguments made by the claimants have been partly vindicated,
- 9 in their own eyes at least, by the fact that compensation has nevertheless been paid. Some
- 10 community members are also aware of the fact that some foreign organisations and
- 11 experts dispute the company's claims about the impact of its operations on local
- 12 ecosystems or about the effectiveness of measures taken to mitigate this impact (e.g.
- 13 Bosshard 1996; Ruede 1999).
- 14 **Table 2:** Key drivers of coastal ecosystem change in Lihir.

| INTERNAL AND DIRECT | EXTERNAL AND DIRECT |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> • Direct environmental impact of industrial development (mining) on land (pit, stockpiles, roads, infrastructure) and sea (sedimentation) • Intensification of food-cropping systems or hunting, fishing and gathering practices • Clearance of uncultivated forest for expansion of food-cropping systems • Discharge of domestic waste material by local households • Accidental introduction of exotic species or varieties of flora and fauna (Giant African Snail, various weeds) | <ul style="list-style-type: none"> • Tectonic disturbances (volcanic eruptions, earthquakes and tsunamis) • Freak weather events with localised impacts |
| INTERNAL AND INDIRECT | EXTERNAL AND INDIRECT |
| <ul style="list-style-type: none"> • Volume of human migration and social transactions across boundaries of traditional community domains • Change in value or policy component of indigenous resource management regimes • Destabilisation of customary tenure systems, wealth distribution and food security, and increase in land pressure as a result of immigration and the monetisation of customary feasting institutions • Devaluation of local custom and customary leadership • Loss of agricultural knowledge and skills. | <ul style="list-style-type: none"> • National policy component of sectoral resource management regimes • Price of commodity exports, imported food and imported fuel • Scientific and technical innovations in agriculture, energy and water supply |

- 15

5.2 Ranking of Drivers in Terms of Impact

From the company's point of view, the most significant drivers of ecosystem change outside of its own lease areas are the rapid growth of the local population and the change in local consumption patterns which have been brought about by the infusion of additional cash incomes into the local economy. From this perspective, population pressure was already transforming local ecosystems in the period before the start of mine construction, and even before the discovery of the gold deposit in 1983, and its impact will accelerate as cash incomes begin to shrink with the progressive reduction of exports and employment in the mining economy, because a population two or three times its former size will be thrown back to reliance on a subsistence base that will no longer be able to support them.

From the community's point of view, the company is responsible for degrading that same subsistence base through its clearance and excavation of agricultural land, through the discharge of tailings and sediments into the sea, and through the impact of noise, fumes, smoke and dust on the local flora and fauna. From this perspective, the population has only outgrown the rest of the local subsistence base because the mine has acted as a magnet for people who would either have stayed away or left the islands in search of a better life. Furthermore, the impact of the mining economy on indigenous social and cultural institutions is held to be the indirect driver of any changes in local people's behaviour which might themselves be counted as direct drivers of ecosystem change.

The mining company and the local community might at least agree that the key drivers of ecosystem change over the last two decades have been internal rather than external, which means they are either under the control of the company or under the control of the community. The company's presence undoubtedly helped to insulate the islanders from the effect of the drought in 1997, because the company had already made substantial improvements to village water supplies throughout the islands, while local cash incomes from the process of mine construction reduced the reliance of local households on locally grown food. The national government's mining policy could be held responsible for the development of the mining operation in the first place, but local community leaders have continually asserted their own power to dictate the conditions and pace of the development process. External price fluctuations may have affected the amounts of money flowing through the local economy, but not to an extent that would have fundamentally modified the environmental impact of economic change.

5.3 Interactions and Feedbacks between Drivers

There has been some debate amongst social scientists about the relationship between the social and environmental impacts of large-scale mining operations in PNG, especially in the wake of the landowner rebellion that led to the closure of the Panguna (Bougainville) copper mine in 1989. This can be construed as a debate about the vicious circles or negative feedback loops which caused that particular event, but which can also be detected in the attitudes and practices of local communities at other major mine sites. One line of argument (e.g. Filer 1990) suggests that an exaggerated form of anxiety or paranoia about the environmental impact of mining reflects a complex process of social disintegration initiated by the unequal distribution of compensation and benefits between different sections of the local community. An alternative line of argument (e.g. O'Faircheallaigh 1992) suggests that local social institutions are undermined when community members realise that they have not been adequately compensated for the

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- 1 actual environmental damage caused by mining operations. Lihirians themselves prefer
- 2 this second line of argument, despite the unprecedented value of the compensation
- 3 package negotiated by their community leaders, and despite the widespread evidence of
- 4 discontent about the way that mine-related incomes have since been distributed (Filer and
- 5 Mandie-Filer 1998).

- 6 While Lihirian community leaders have continually made reference to the need to
- 7 maintain and support the institutions of 'custom' in the face of the mining economy, and a
- 8 significant portion of the wealth derived from the mining economy has in fact been
- 9 absorbed into the local ceremonial economy, the demand for extra pigs and yams as key
- 10 items of currency within that ceremonial economy needs to be considered as a driver of
- 11 ecosystem change in its own right, because pigs and yams both make their own demands
- 12 on the local food-cropping systems. Ceremonial yam gardens in particular are likely to
- 13 have a significant impact, as there is much prestige associated with the size of yams
- 14 presented at feasts, and the most effective means of achieving large yam sizes is to clear
- 15 new areas of primary forest, since soil fertility tends to be higher here than on land that
- 16 has been under fallow. Ceremonial yam gardens also tend to be much larger in area than
- 17 gardens intended for domestic subsistence.

- 18 How would the transfer of so many Lihirian men (and some Lihirian women) into the
- 19 mining economy have been driving the process of change? Filer and Jackson (1989:36)
- 20 suggested that a reduction in the amount of male labour in the food-cropping system
- 21 would lead to inadequate fencing of gardens and greater destruction by pigs, and
- 22 Bonnell's (1992) observations in a village close to the mine site indicate that this was
- 23 already happening in the latter part of the exploration phase. However, one of the most
- 24 popular aspects of the assistance which company and government personnel have recently
- 25 been providing to subsistence farmers has been the distribution of pig wire at cost price.
- 26 This wire has replaced the more labour-intensive bamboo as the preferred material for
- 27 fencing gardens, but this in turn has had the effect of decreasing fallow periods in areas
- 28 where access to bamboo formerly determined the choice of garden location. In the past,
- 29 locating new food gardens close to large stands of bamboo had the effect of spreading
- 30 gardens around in space and time, thus keeping fallow periods close to the 'typical'
- 31 period of 10 years. Since the introduction of pig wire, farmers have been making their
- 32 normal food gardens on land closer to their villages, which in many cases has only been
- 33 fallowed for periods of 2-5 years.

- 34 While the attachment of monetary values to blocks of customary land within the areas
- 35 now leased by the mining company has understandably given rise to several disputes
- 36 about the identity of the customary owners, there is also anecdotal evidence of an increase
- 37 in the number of land disputes on the small islands of Ihot. Some people on Masahet
- 38 have expressed the view that land disputes on their island have become more frequent and
- 39 intractable because local 'big men' have begun to lose their customary control over the
- 40 local gardening regime, but they hesitated to blame this loss of custom on the impact of
- 41 the mine (Filer and Mandie-Filer 1998).

- 42 It is more plausible to argue that the loss of agricultural and other indigenous knowledge
- 43 is interacting with rapid population growth, the devaluation of customary leadership, and
- 44 the destabilisation of customary land tenure regimes, to intensify the process of forest
- 45 clearance and land degradation. Much of the cultural knowledge connected with the
- 46 management of local ecosystems is being lost as a result of the acculturating influence of

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- 1 the mining economy, and in that respect, the process of accelerated (and ultimately
- 2 unsustainable) development still looks like the key driver of change.

• 3 **5.4 Human Consciousness and Control of Drivers**

- 4 While Lihirians are more than willing to reflect on the social conflict which has arisen
- 5 over the distribution of mineral wealth within the local community, they are less inclined
- 6 to accept responsibility for dealing with this problem through their own political
- 7 institutions, and prefer to seek a solution by making additional demands on the mining
- 8 company. These demands are generally based on the assertion that mining has damaged
- 9 local ecosystems in ways that are not covered by existing compensation agreements, or
- 10 that the mining company should compensate local people for all forms of environmental
- 11 damage, regardless of who is responsible for them.

- 12 People living well outside the so-called ‘mine-affected area’ are deeply concerned about
- 13 the risk to their health and their resources posed by the smoke which comes out of the
- 14 chimneys in the processing plant, and which is then supposedly brought back to earth in
- 15 the form of polluted ‘acid’ rain (Macintyre and Foale 2004a,b). This could be seen as a
- 16 perfectly reasonable fear which anyone in the same position would be entitled to hold in
- 17 the absence of convincing scientific evidence. Or it could be seen as evidence of a
- 18 growing tendency to blame the mine for any loss of ecosystem services, even when there
- 19 is evidence that local people themselves are responsible for other internal drivers which
- 20 are causing these losses. In this particular case, it could also be seen as a reflection of the
- 21 fact that smoke has traditionally been a significant medium or vehicle for the exercise of
- 22 magical power, and fear of the company’s smoke is thus accentuated by this particular
- 23 feature of the indigenous knowledge framework.

- 24 **Plate 20:** The smoke plume from the mine’s processing plant. [INSERT]

- 25 There are other cases in which the allocation of blame to the mining company is more
- 26 clearly part of a ‘compensation culture’ or a simple desire to relieve the mining company
- 27 of as much money as possible before it disappears over the horizon. For example, when
- 28 the Giant African Snails first made their appearance in 1998, most Lihirians were
- 29 prepared to concede that they had been brought in with the foodstuffs privately imported
- 30 to the islands, but most also thought that the mining company should pay for the work of
- 31 eradication or compensate local villagers for any damage to their gardens. Likewise,
- 32 when several pigs died in a village close to the mine site, their owners saw this as an
- 33 opportunity to claim compensation from the company, and were very disappointed when
- 34 an autopsy showed that they had died from malnutrition (Macintyre and Foale 2004a).

• 35 **6 Ecosystem Conditions and Trends**

• 36 **6.1 Plantations and Smallholdings (Coconut and Cocoa)**

- 37 In 1968, the Australian administration estimated that there were 152,000 mature and
- 38 88,000 immature coconut palms growing on customary land in Lihir (Gormley 1968), and
- 39 figures for copra exports suggest an equivalent number in the plantations managed by
- 40 Europeans. The number of palms growing on customary land was thought to be five
- 41 times the number required to supply local subsistence needs, and the balance should have
- 42 been available to supply the export trade, but exports were running at only 25% of their
- 43 potential because of a recent plague of coconut spathe bugs (*Axiagustus* sp.) (Gormley

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- 1 1968; O’Sullivan 1973). The village palms seem to have recovered rather more quickly
- 2 from this affliction than those on the commercial plantations (Filer and Jackson 1989:83),
- 3 where new planting seems to have ceased by the 1970s. People on the small islands of
- 4 Ihot were claiming to have cut down mature palms to make more space for food gardens
- 5 during the 1980s (ibid:38-40), and several thousand palms were later removed from
- 6 Niolam to make way for the mine and its associated infrastructure. No attempt has since
- 7 been made to estimate the number of remaining palms by reference to aerial photographs
- 8 taken during the course of mine development.

- 9 During the mid-1980s, the government was providing subsidies to local farmers to plant
- 10 one-hectare hybrid cocoa blocks, and a total of 104 hectares was planted (mainly in the
- 11 southern part of Niolam) over a 3-year period from 1985 to 1987 (Filer and Jackson
- 12 1989:88). However, the annual rate of planting then went into decline because of a fall in
- 13 cocoa prices on the world market, and it is unlikely that the total area planted to cocoa
- 14 was ever in excess of 500 hectares.

- 15 The mining company and the government have both made some efforts to resurrect the
- 16 plantation economy since the mine went into operation, because they recognise the need
- 17 to plan for a steep decline in local cash incomes from the mining economy. The
- 18 government distributed 5000 hybrid coconut seedlings to local farmers in 2001-2, which
- 19 should have covered 28 hectares of land, but it is not known how many of the seedlings
- 20 survived.

• 21 **6.2 Food Gardens and Forest Fallows**

- 22 There are clear signs that the area under cultivation is expanding rapidly under the burden
- 23 of Lihir’s swelling population. There is also a great deal of anecdotal evidence of
- 24 continued shortening of fallow periods in northeastern Niolam and on the small islands of
- 25 Ihot. Degradation of the gardening zone in these areas is not being alleviated by the
- 26 extension or intensification of gardening on customary land in other parts of Niolam
- 27 because local landowners are increasingly concerned to maintain their own asset base
- 28 from encroachment by outsiders. That is why the process of expansion and
- 29 intensification is currently focused on areas currently held under lease by the mining
- 30 company which were previously alienated from customary ownership during the colonial
- 31 period.

• 32 **6.3 Orchards and Sago Groves**

- 33 Lihirians tend to complain that the smoke generated by the mine’s processing plant has
- 34 reduced the quantity and quality of the harvest from their fruit and nut trees, but there is
- 35 as yet no scientific evidence to support these claims and some observational evidence to
- 36 the contrary. They also tend to complain of a decline in the bird and bat populations
- 37 associated with these tree crops, but this could be explained by a rapid increase in the
- 38 number of slingshots in the hands of local children.

- 39 Since Lihirians have traditionally used sago palms primarily as a source of building
- 40 material, the impact of a growing population on a fairly small resource base should so far
- 41 have been mitigated by the construction of houses with corrugated iron roofing. However,
- 42 there is presently no firm evidence of change in the physical extent or internal
- 43 composition of the local sago groves.

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6.4 Uncultivated Forest and Grasslands

The shortening of fallow cycles in northeastern Niolam and the small island of Malie and Masahet has almost certainly resulted in the extension of those areas of scrubland, grassland, or fern cover which are degraded beyond the point at which they could still be managed as part of the zone of shifting cultivation. However, the physical extent of this ecological switch has not yet been measured, partly because the mining company is reluctant to measure any kind of environmental change for which it is not prepared to accept a degree of responsibility.

For reasons previously mentioned, there does not seem to have been any dramatic reduction in the area of ‘uncultivated’ (or rarely cultivated) forest on the main island of Niolam. That is because the mine and its associated infrastructure (including the Niolam ring road) have all been developed in the narrow coastal belt where the human population of the islands was (and still is) concentrated. However, the most recent aerial photographic data are from 1998, and there may have been significant forest clearance in some parts of the interior since then, particularly along the road which runs inland from the mining township at Londolovit.

6.5 Freshwater Systems

Most of the small creeks on Lihir appear to remain in good condition despite rapidly expanding agriculture, though we have little scientific data. The cause of a mysterious die-off of fresh-water prawns (probably *Macrobrachium* sp.) near Kunaye in 2002 was never found. It was unlikely to be linked to the mining operation. Village water supply systems, including wells that tap the freshwater lens near the coast, have been installed by the government over the years, with an increase in numbers in the past two years.

6.6 Mangrove Swamps

Since mangroves are concentrated on the western side of Niolam, they have not been affected by development of the mine. As in the case of sago, the growth of local cash incomes should have so far mitigated any increase in demand for the use of mangroves for firewood or building timber, but the mining company has not been monitoring this pattern of consumption.

6.7 Coral Reefs

In contrast to some of the other biological communities of Lihir, the condition of the local coral reefs has certainly been a major focus of attention and measurement for the mining company. The localised impact of sediments from barge dumping and mine-site runoff on the coral reef ecosystems at Lihir has been well-documented (Rotmann 2001a; Brewer et al. 2003; Thomas et al. 2003). To date, sediments have produced the most significant impact on coral survival. Measured sediment loads were characterized by Thomas et al. (2003) as ‘severe’ (>30mg/litre at <1km radius from mine site), ‘transitional’ (between 15 and 30mg/litre at <2km from mine site), and ‘minor’ (<5mg/litre at between 2 and 9km from mine site). High levels of coral mortality and stress occurred within the ‘severe’ zone (Rotmann 2001a, confirmed by MA team observation). According to measures of coral (*Porites* spp.) tissue thickness and percent colony mortality, coral health at two sites in the ‘minor’ zone -- at 2km and 8km respectively from the mine site -- was not significantly different from controls (Rotmann 2001a). Rogers (1990) regards levels of

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- 1 sedimentation less than 10mg/litre as not stressful to corals. Due mainly to the location of
- 2 the tailings outfall at 128m below sea level, sediments and heavy metals in the deep sea
- 3 tailings are unlikely to impact on coral reefs, and as yet there is no evidence of any impact
- 4 (NSR 2001).

- 5 **6.8 Seagrass Beds and Soft Bottoms**

- 6 There are significant areas of seagrass on the southern and western coast of Niolam, and
- 7 between Malie and Sanambiet, but there is no data on the status of these, apart from
- 8 observations that they are unlikely to have been significantly impacted by increased
- 9 fishing activity, or mining-related sedimentation, due to their distance from the mine site.

- 10 **7 Responses to Ecosystem Change**

- 11 **7.1 Population Pressure on Scarce Subsistence Resources**

- 12 There is clear evidence that the people of Ihot, especially those of Malie and Masahet
- 13 islands, had been responding to the local scarcity of cultivable land and other subsistence
- 14 resources for several decades – if not centuries – before the discovery of the gold deposit
- 15 in 1983 (Filer and Jackson 1989:38-41). The first response, which probably dates back to
- 16 the pre-colonial era, was to increase the productivity of the food-cropping system through
- 17 the construction of walls and fences, more intensive tillage of the soil, and the
- 18 organisation of planting cycles under the supervision of local ‘big men’.

- 19 The second response was to access land and other resources in the northeastern part of
- 20 Niolam by using connections of kinship or marriage with the customary owners. This
- 21 response was already evident in the 1960s, when a government official noted the social
- 22 tension which had arisen between the people of Masahet and those of northeastern
- 23 Niolam after the latter had allowed the former to plant copra on the main island (Gormley
- 24 1968). In the 1980s, it was noted that Masahet people were now making food gardens in
- 25 the same area, and also taking bamboo and sago from Niolam for use as building
- 26 materials (Filer and Jackson 1989:39). It is likely that these activities also had a long
- 27 pedigree, but there was less evidence of social tension because they did not entail a claim
- 28 to cash incomes over a lengthy period of time.

- 29 The third response was to take advantage of the educational opportunities offered by the
- 30 Catholic church to export skilled labour to the rest of PNG. In 1979, more than 12% of
- 31 the indigenous population of Ihot was recorded as being absent from the islands, by
- 32 comparison with 7% of the population of Niolam (ibid:31), and a higher proportion of the
- 33 Ihot population had acquired a secondary or tertiary education (ibid:122).

- 34 The social impact assessment of the gold mine recognised the capacity of the mining
- 35 economy to absorb surplus labour and reduce the level of demand for local ecosystem
- 36 services in the medium term, but also recommended that a program of action to raise the
- 37 productivity of local agriculture or reduce the local birth rate should be adopted, either by
- 38 the mining company or the government, to address the long-term problem (Filer and
- 39 Jackson 1989:41). It was noted that some attempts had already been made by the
- 40 Catholic church and the mining company to encourage commercial exploitation of
- 41 inshore marine resources around the small islands as a way of alleviating pressure on
- 42 gardening land, but these had not been very successful (ibid:33).

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- 1 The local influence of the Catholic church, combined with the subordinate status of
- 2 women in Lihirian society, has discouraged the implementation of a program of birth
- 3 control. The company and the government have both made sporadic attempts to promote
- 4 forms of economic enterprise, including commercial agriculture, whose viability is not
- 5 dependent on the presence of the mining company, but the local ‘compensation culture’
- 6 has limited the success of these efforts.

• 7 **7.2 Environmental Impact of Mining and Mineral Wealth**

- 8 Responses to this issue are politically charged by the combination of the local
- 9 ‘compensation culture’ with the claims of Western advocates who deplore the social and
- 10 environmental impact of large-scale mining operations on indigenous peoples or tropical
- 11 ecosystems.
- 12 The PNG government approved the development of the mine under the terms of the
- 13 *Environmental Planning Act* (1978), which means that the company is obliged to
- 14 implement an environmental management and monitoring program which was part of the
- 15 ‘integrated benefits package’ negotiated with local community leaders in 1995. The
- 16 company and the government both maintain that deep-sea tailings disposal will not result
- 17 in extensive and irreversible damage to Lihir’s marine ecosystems, and that all discharges
- 18 from the mining fall within internationally accepted standards. The environmental
- 19 monitoring program is designed to support these assertions with scientific evidence,
- 20 although local people are not greatly impressed by the weight of this evidence.
- 21 The company is also obliged to monitor the social impact of its operations under the
- 22 terms of government policy and by agreement with the local community, although some
- 23 community leaders have occasionally argued that they should do this themselves. This
- 24 involves the company in a wider dialogue with the community about the ways in which
- 25 changes to the local economy, society and culture are having their own independent effect
- 26 on the natural environment. One obvious example would be the conversion of mineral
- 27 wealth into various forms of waste discharged by the household economy, rather than the
- 28 mining economy. These range from plastic bags and torch batteries to the burnt-out
- 29 bodies of old motor vehicles. In this case also, there is a widespread community
- 30 expectation that the company should take responsibility for every aspect of waste
- 31 management on the islands. The company has gone some way to meet this expectation in
- 32 the ‘mine-affected area’ through the improvements made to local water supplies, the
- 33 organisation of a system of rubbish collection, the sponsorship of recycling enterprises,
- 34 and a program of environmental education in the local schools.

• 35 **8 Planning for Mine Closure**

- 36 The mining company has already been planning for mine closure for several years, so this
- 37 could be seen as a ‘response’, though it is not specifically a response to ecosystem change.
- 38 The mine is currently expected to close in 2032, but the real incomes which the mine
- 39 provides to Lihirian households will have fallen to less than 20% of their current levels
- 40 when open-pit mining ends in 2012, and will then continue to diminish until the point of
- 41 closure (Finlayson 2002).
- 42 At both of these points in time, many residents will leave the islands, but the number who
- 43 leave will be no match for the increase in the total population since the start of mine
- 44 construction. Under current economic scenarios, the mining industry is unlikely to

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- 1 provide employment elsewhere for those who have specialist skills as mineworkers, nor
- 2 will there be many other job opportunities available in the urban or public sectors. This
- 3 means that local demand for local ecosystem services will continue to increase, over and
- 4 above what would be expected from natural population growth, in the medium to long
- 5 term.

- 6 The mining company has taken the lead in establishing a Sustainable Development
- 7 Committee, which includes representatives from the government and the local community,
- 8 in order to develop joint programs in preparation for mine closure. The Committee is
- 9 focusing on four key areas -- economic development, social development, human capital
- 10 development, and infrastructure and utilities. However, community participation in this
- 11 body has been inhibited by continuing arguments over the terms of the original
- 12 'integrated benefits package'.

- 13 It is unlikely that Lihirians will ever make much money from the commercial sale of fish
- 14 or other marine resources, either for domestic sale or for export, because of a combination
- 15 of cultural, economic and technical constraints. So while it may be true that local fish
- 16 stocks are vulnerable to higher levels of exploitation, there is not much indication that this
- 17 will occur while the mine continues to operate, or even after it closes.

- 18 Mining company and government officials see greater potential in developing a new
- 19 version of the local plantation economy because of the number of local farmers who still
- 20 show an interest in planting hybrid coconuts. This could involve the production of high-
- 21 grade cold pressed coconut oil by means of the recently developed Direct Micro
- 22 Expelling (DME) technology (Macintyre and Foale 2003). Lihir already imports some
- 23 DME oil produced in another part of PNG, and this is proving to be a product with a
- 24 potentially large export market, but there would still need to be a strong emphasis on
- 25 market development prior to any agricultural and technical inputs.

- 26 **9 Conclusion**

- 27 When one considers that the amount of scientific information already collected about the
- 28 people and ecosystems of the Lihir island group probably exceeds the amount collected
- 29 about any other area of equivalent size or population in PNG, with the possible exception
- 30 of the area immediately downstream of the Ok Tedi mine in Western Province, it is
- 31 interesting to note how little is still known about the current dynamics of the relationship
- 32 between ecosystem services and human well-being in this area. This can partly be
- 33 explained by the way in which the social and environmental impacts of large-scale
- 34 mining operations are assessed and monitored in order to comply with government
- 35 regulations and company policies, but in the Lihir case at least, it also reflects some of the
- 36 difficulties posed by the actual and perceived impacts of the mining operation for the
- 37 process of scientific inquiry. That is because the conduct and outcome of any type of
- 38 ecosystem assessment becomes a hostage to the ongoing process of negotiation and
- 39 disputation between the mining company and the local community about the value of
- 40 these impacts. And that is also the reason why a 'community-based' ecosystem
- 41 assessment would be a very difficult thing to organize in this particular social and
- 42 economic environment.

- 43 The choice of Lihir as the site for a local assessment was not only driven by the
- 44 availability of data, or the knowledge of the authors, but also by the fact this particular
- 45 segment of PNG's coastal zone is the one that has experience the most dramatic social,

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- 1 economic and ecological transformation over the course of the last decade. The only
- 2 comparable case would be the island of Misima in Milne Bay Province, where another
- 3 gold mine has just ceased operation. However, while Misima is an island of similar size
- 4 to Niolam, its mining operation was not of a scale or duration to compare to the mine on
- 5 Niolam, nor was it associated with a dramatic increase in the local population. Lessons
- 6 learnt from an evaluation of the social and environmental impact of mine closure on
- 7 Misima may have some relevance for the planning of mine closure on Niolam, but this

- 8 By pumping money into the local household economy, Lihir's mining economy has
- 9 brought about a short-term reduction in the degree of local people's dependence on local
- 10 ecosystem services. While development of the mine has clearly reduced the supply of
- 11 some such services through the clearance of vegetation and the marine deposition of
- 12 waste material, this impact has been offset by the increased supply of some services, such
- 13 as fresh water, and a transformation in the use of others, such as geothermal energy.

- 14 The outstanding questions posed by this assessment concern the resilience and
- 15 sustainability of the 'human ecosystems' or 'social-ecological systems' which now exist
- 16 in the mine-affected area and in the rest of the Lihir island group. In this respect, there is
- 17 something of a paradox apparent in the cash-fuelled expansion of the ceremonial
- 18 economy and the simultaneous erosion of traditional technical and environmental
- 19 knowledge. If it were possible to engage community members in the construction of
- 20 alternative scenarios to represent their future response to the decline and fall of the
- 21 mining economy, it might be possible to explore the ramifications of this paradox. But at
- 22 the present stage of the mining operation, this is a daunting task.

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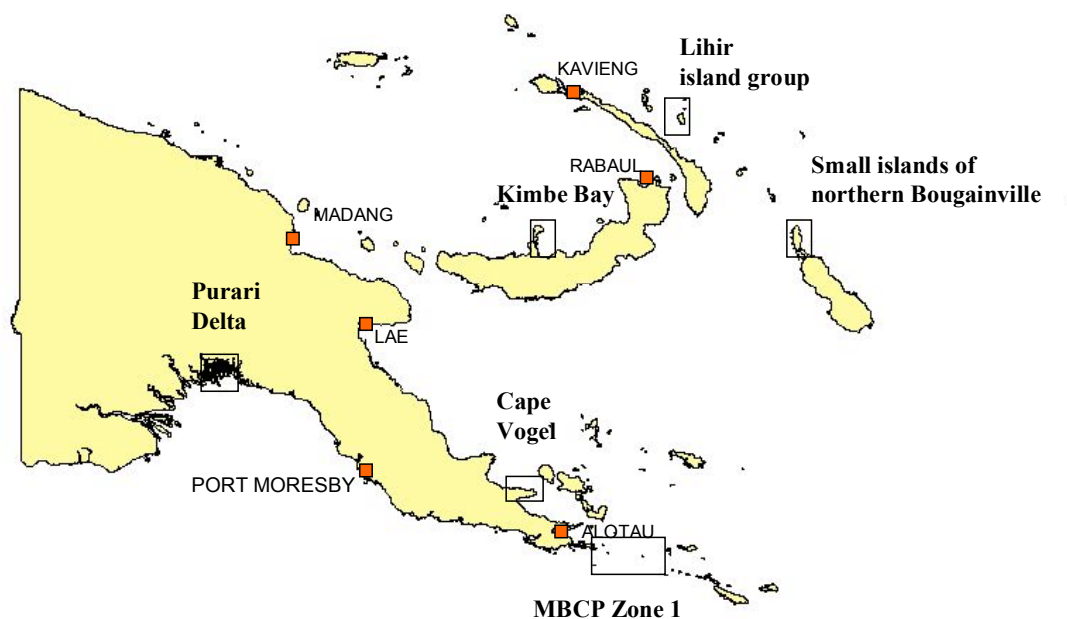
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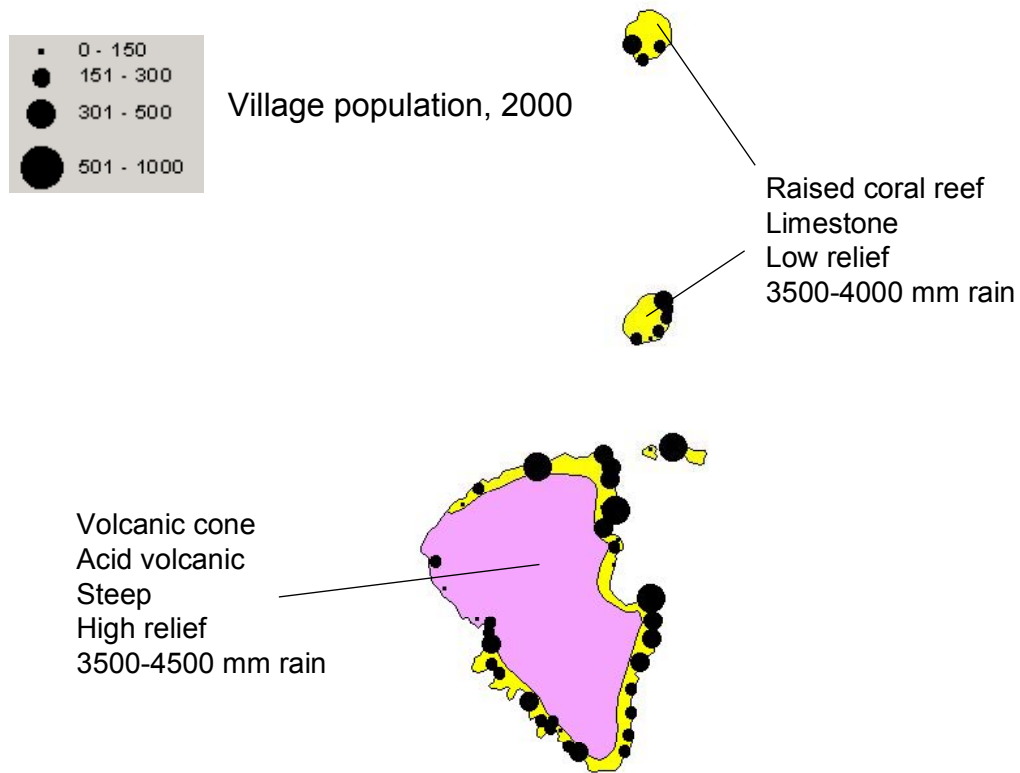
- 1 **Figure 1:** Local assessment sites in Papua New Guinea, including Lihir island group.



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- 1 **Figure 2:** Resource Mapping Units in the Lihir island group.

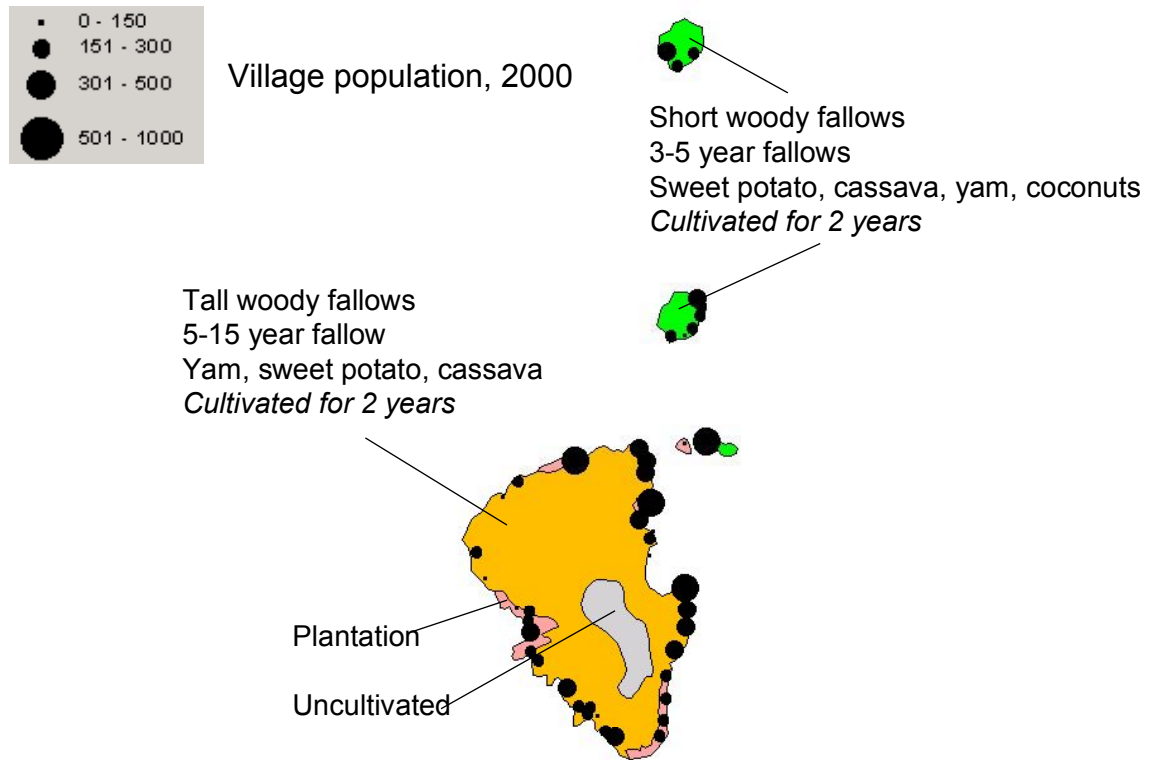


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Source: PNG Resource Information System.

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- 1 **Figure 3:** Food-cropping systems in the Lihir island group.

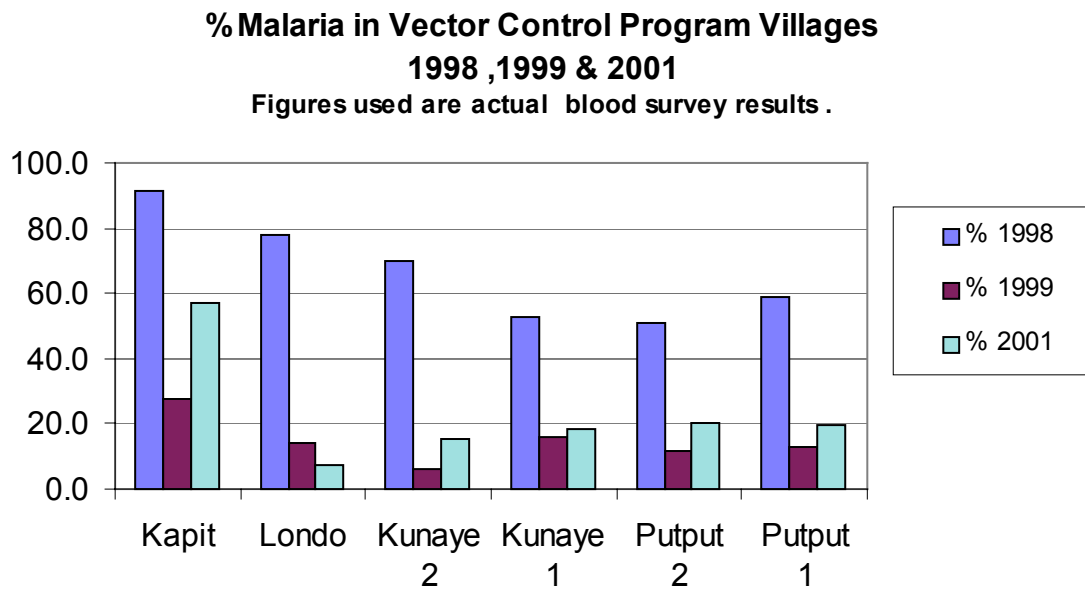


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Source: Hide et al. 1996.

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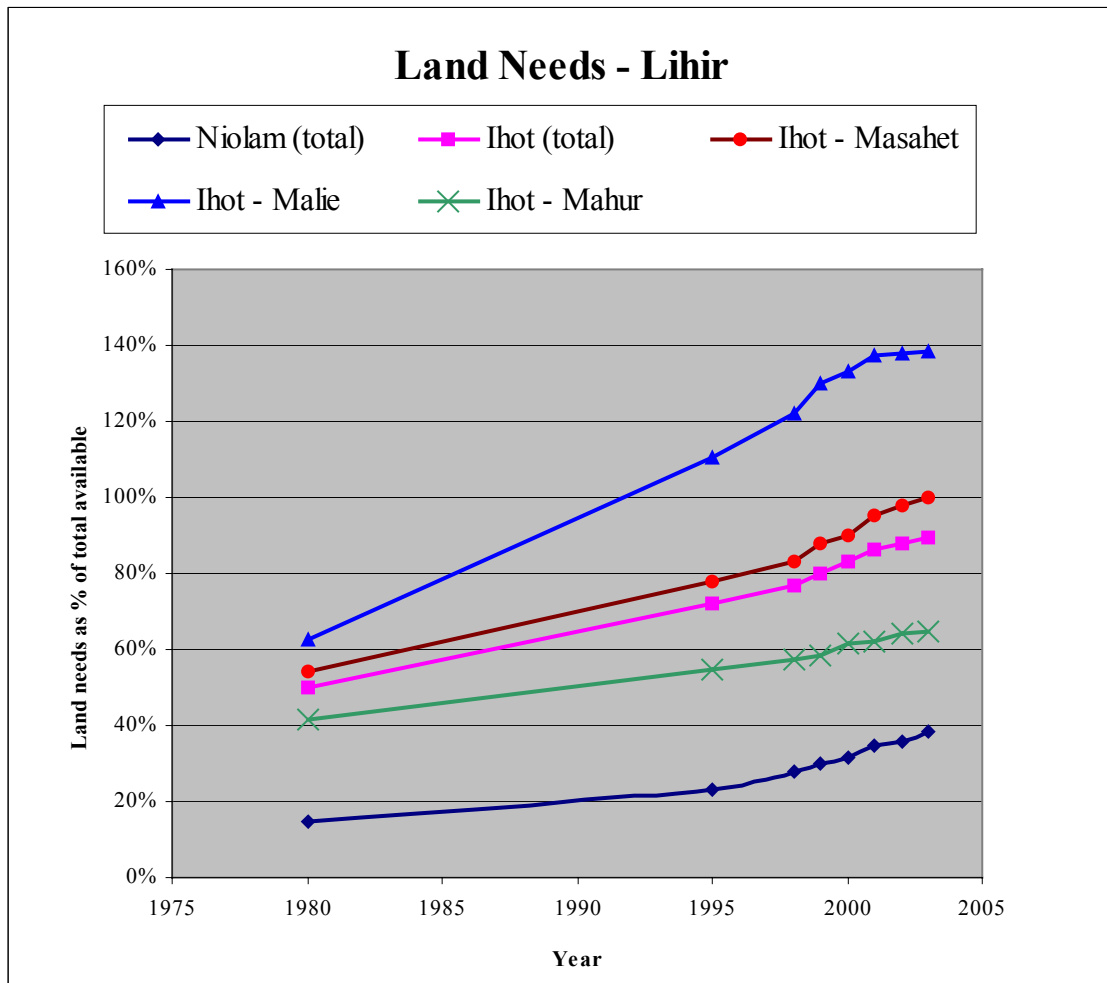
- 1 **Figure 4:** Distribution of malaria in selected villages of Niolam.



- 2 **Source:** Lihir Management Company records.
- 3

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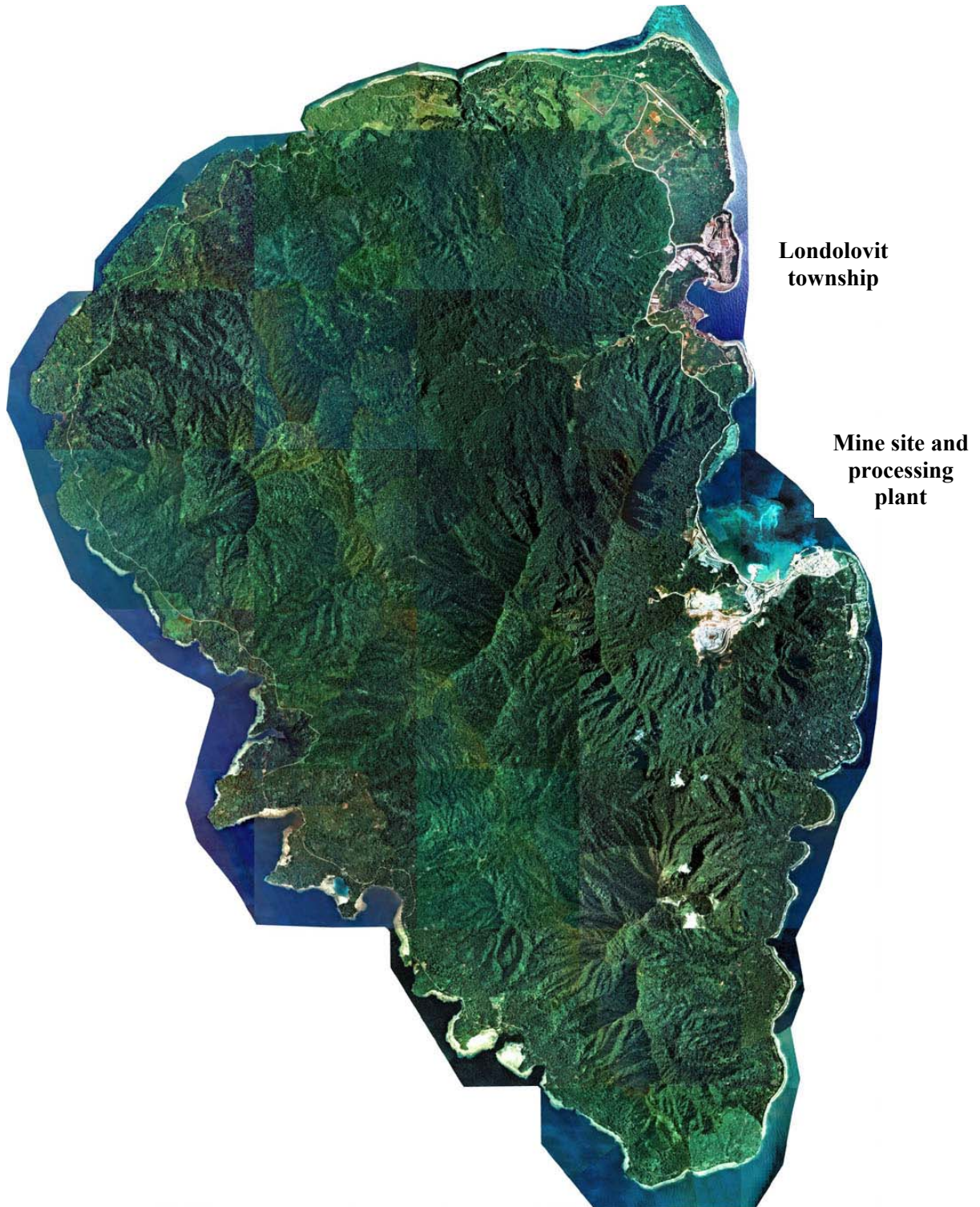
- 1 **Figure 5:** Land required for gardening as percent of land available in different parts of
- 2 Lihir, 1980-2003.



- 3
- 4 **Source:** Macintyre and Foale 2001:27.
- 5

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- 1 **Plate 1:** Composite aerial photograph of Niolam island, showing the mine site and mining
- 2 township.



- 3
- 4 Photograph courtesy of Lihir Management Company.
- 5

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- 1 **Plate 2:** Aerial view of the mine pit, with Luise Harbour in the background.



- 2
- 3 Photograph courtesy of Lihir Management Company.
- 4 **Plate 3:** Aerial view of Londolovit township, with the small islands of Ihot in the
- 5 background.



- 6
- 7 Photograph by Simon Foale.
- 8

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- 1 **Plate 4:** Preparations for a feast on Masahet island.



- 2
- 3 Photograph by Simon Foale.
- 4

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- 1 **Plate 5:** Inter-tidal platform on Masahet island.



- 2
- 3 Photograph by Simon Foale.
- 4 **Plate 6:** Coral formation on the Western side of Niolam.



- 5
- 6 Photograph by Simon Foale.
- 7

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- 1 **Plate 7:** Coconuts and bush fallows in the lowest altitudinal zone of Niolam island.



- 2
- 3 Photograph by Simon Foale.
- 4

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- 1 **Plate 8:** New garden clearance on the western side of Niolam.



- 2
- 3 Photograph by Simon Foale.
- 4 **Plate 9:** New garden clearance on Malie island (with megapode nesting hole).



- 5
- 6 Photograph by Simon Foale.
- 7

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- 1 **Plate 10:** Ferns (*malo*) on Masahet island.



- 2
- 3 Photograph by Simon Foale.

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- 1 **Plate 11:** House constructed by the mining company under the Village Development
- 2 Scheme.



- 3
- 4 Photograph by Simon Foale.
- 5

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- 1 **Plate 12:** Aerial photograph from 1998, showing parts of the mining companies
- 2 Londolovit leases (bounded in green), and the area which has since been cleared for
- 3 cultivation by Malie islanders (bounded in red).



- 4
- 5 Photograph courtesy of Lihir Management Company.
- 6

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- 1 **Plate 13:** Geothermal energy harnessed as part of the mine dewatering process.



- 2 Photograph by Martha Macintyre.
- 3

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- 1 **Plate 14:** Village cemetery adjacent to the mine site.



- 2
- 3 Photograph by Martha Macintyre.
- 4

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- 1 **Plate 15:** Domestic rubbish on beach adjacent to the mine site.



- 2
- 3 Photograph by Simon Foale.
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- 1 **Plate 16:** Boys hunting parrots with slingshots.



- 2
- 3 Photograph by Simon Foale.

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- 1 **Plate 17:** Corporate protection of turtle nesting sites near the mine site.



- 2
- 3 Photograph by Simon Foale.
- 4 **Plate 18:** Cultivating stony ground on Masahet island.



- 5
- 6 Photograph by Simon Foale.
- 7

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- 1 **Plate 19:** Traditional fishing methods applied on the edge of the inter-tidal platform.



- 2
- 3 Photograph by Simon Foale.
- 4 **Plate 20:** The smoke plume from the mine's processing plant.



- 5
- 6 Photograph by Simon Foale.