MINING THE REEFS AND CAYS: CORAL, GUANO AND ROCK PHOSPHATE EXTRACTION IN THE GREAT BARRIER REEF, AUSTRALIA, 1863-1945

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Abstract

Scholarly attention has recently focused on the extent of the deterioration of the Great Barrier Reef and several authors have attempted to place that decline into historical context. We present documentary and oral history evidence that the extent and severity of mining in the Great Barrier Reef has been hitherto neglected in environmental histories of the ecosystem. Extraction of phosphatic sandstone, guano, rock phosphate and coral from many islands, cays and coral reefs have resulted in extensive transformations of some habitats. In particular, Raine, Lady Elliot, Lady Musgrave, North West and Holbourne Islands experienced intensive mining for guano and rock phosphate, while more sustained guano mining took place at Upolu, Oyster and Michaelmas Cays, prior to 1940. Coral mining – which has not previously been documented for the Great Barrier Reef – also took place in at least twelve locations between 1900 and 1940, with the result that thousands of tons of coral were removed from some reefs and pulverised to produce agricultural and industrial lime. This account suggests that historical mining in the Great Barrier Reef has left impacts in the landscape of several islands and cays. Further scientific research and monitoring is required to elucidate the impacts of coral mining, although comparisons with coral mining sites elsewhere in the world suggests that it is reasonable to presume that the impacts of that activity were severe for parts of several reefs, including Snapper Island, Kings and Alexandra Reefs.

Key words: Queensland; Great Barrier Reef; coral mining; agricultural lime; guano

Introduction

Increasing concern has been expressed recently about the state of coral reefs worldwide (Jackson *et al.* 2001, 629; Pandolfi *et al.* 2003, 955). Many authors have claimed that global marine environments are experiencing critical decline as a result of over-harvesting, pollution and climate change (Bellwood *et al.* 2004, 827; Hughes *et al.* 2003, 929; Hughes *et al.* 2005, 1; Pandolfi *et al.* 2005, 1725; Pandolfi *et al.* 2003, 955-956). In this context, the state of the Great Barrier Reef of Australia has been scrutinised; while the Great Barrier Reef is regarded as one of the most 'pristine' coral reefs in the world, the ecosystem nevertheless shows evidence of system-wide decline (Bellwood *et al.* 2004, 827), including a significant reduction in coral cover during the last 40 years (Bellwood *et al.* 2004, 828; see also Pandolfi *et al.* 2005, 1725). Concerns about impacts of deteriorating water quality in the Great Barrier Reef, which some authors have argued is linked with nutrient and sediment run-off from the adjacent Queensland coast, have attracted scholarly attention (Furnas 2003; McCulloch *et al.* 2003; Williams 2001; Williams *et al.* 2002). Other authors have investigated the impact of increasing sea surface temperatures (SSTs), to which coral bleaching episodes in the Great Barrier Reef have been attributed (Hoegh-Guldberg 1999; Lough 1999). Commercial and recreational fishing, tourism and coastal development represent other impacts on the ecosystem, as Lawrence *et al.* (2002, 207) have acknowledged. Hence, the reports of two major investigations, by the Australian Commonwealth and Queensland Governments respectively, found 'clear evidence' of deteriorating habitats in the Great Barrier Reef as

a result of human activities (Commonwealth of Australia, Productivity Commission 2003, xxviii; Queensland Government, Science Panel 2003, 9).

In an effort to assess the magnitude and intensity of this deterioration of the Great Barrier Reef, some attempts have been made to place changes in the ecosystem into historical perspective (Bowen and Bowen 2002; Bowen 1994). However, few other environmental histories of the Great Barrier Reef have been written, and the studies by Bowen, and by Bowen and Bowen, provide limited information about specific changes in particular coral reefs. Hughes *et al.* (2005, 2) acknowledged that 'if we ignore history and are unaware of trajectories of change, then a system is more likely to be falsely perceived as being stable and pristine'. Yet many environmental historians have acknowledged the difficulties involved in constructing ecological baselines for complex ecosystems that are characterised by constant change (Cronon 1990, pp. 1127-1128; Demeritt 1994, 24-25; Williams 1994, 15). Furthermore, systematic scientific monitoring of the Great Barrier Reef extends back only to around 1970 and scarce scientific information exists for the earlier period. Anecdotal reports of the deterioration of the ecosystem, in contrast, have been frequently expressed and the Great Barrier Reef Marine Park Authority (GBRMPA) – the lead agency with statutory responsibility for the protection and management of the Great Barrier Reef World Heritage Area (GBRWHA) – has sought either to confirm or refute such reports.

In the absence of sufficient scientific data, qualitative sources can illuminate environmental changes in the Great Barrier Reef for the period before 1970. In this

account, we present the results of research into the environmental history of the ecosystem based on extensive analysis of archival and oral history materials. Specifically, we have used many official records of the Queensland Department of Agriculture and Stock (QDAS), Queensland Department of Harbours and Marine (QDHM), Cairns Town Council and Queensland Premier's Department held in the Queensland State Archives (QSA) in Brisbane. These have been supplemented with evidence gained from analysis of official reports of the Queensland Bureau of Sugar Experimental Stations (QBSES), published in the *Queensland Parliamentary Papers* (*QPP*), from export statistics published in the *Statistics of the Colony of Queensland* (*SCQ*), and from a sample of several hundred historical books. Oral history evidence represented a further source of information and 47 original semi-structured interviews were carried out between October 2002 and December 2003 with key and expert informants, who were recruited using a snowballing technique; those interviews were deposited at the GBRMPA Library in Townsville. The evidence was triangulated wherever possible, in order to provide a means of verifying sources and to comply with widely-accepted methodological principles for qualitative research (Gillham 2000; Robertson 2000; Allen and Montell 1981, 3; Denzin and Lincoln 2000).

As a result of our qualitative research, we found considerable evidence for one anthropogenic impact that has been neglected in previous accounts: the historical mining that occurred in the Great Barrier Reef for the extraction of guano, rock phosphate and coral. While the occurrence of guano mining in the Great Barrier Reef has been acknowledged, we provide further details of the extent and impacts of this activity

(Heatwole 1984, 25-44; Hopley 1989, 20; Hopley 1988, 34-35). In addition, no overview of the rock phosphate mining operation at Holbourne Island from 1918 to 1921 has previously been written. Furthermore, while Endean (1982, 300) claimed that no limestone mining had occurred in the Great Barrier Reef, and Carruthers' (1969, 47 and 49) earlier review of limestone mining in the ecosystem stated that little information about the subject existed, we present evidence that coral mining took place at twelve coral reef locations in the Great Barrier Reef between 1900 and 1940; at some reefs, coral mining was both sustained and intensive, and significant environmental impacts occurred. No previous account of coral mining in the Great Barrier Reef has been published, illustrating the value of qualitative techniques in illuminating environmental changes for which scarce other information exists. We discuss these three types of mining in turn, concluding with an assessment of the implications of these accounts for contemporary management of the GBRWHA.

Before commencing the discussion about mining activities on the Great Barrier Reef, some clarification is needed about the historical evidence presented in the account. Substantial information about coral mining was obtained from many records of the QDHM and the QEPA. In particular, valuable material was found in the files relating to the preservation of coral from exploitation, the issue of coral licences, and the *Fish and Oyster Acts, 1914-1935*. However, the records of the QDHM held at the QSA begin and end abruptly, with large discontinuities between some series; archivists at the QSA suggested that other files may have been lost when the Departmental offices in Brisbane were inundated during the Australia Day floods of 1974. The logical sequence of coral

licences suggests that more areas were mined for coral than are revealed by the surviving records. Documentary evidence also suggests that unlicensed coral mining took place at some locations, such as Kings Reef, near Innisfail, before the system of coral licences was introduced. Furthermore, oral history informants revealed that coral mining took place at Snapper Island: a location for which no coral licence was found. Therefore, coral mining probably took place more extensively than this account indicates.

Europeans and exploitation of the Great Barrier Reef's natural resources

The Great Barrier Reef of Australia is the largest complex of coral reefs and associated species on Earth; the location of this structure is shown in Figure 1. The ecosystem extends for over 2,000 kilometres along the north-eastern coast of Queensland, containing more than 3,200 coral reefs and representing one of the most biologically diverse ecosystems known to exist.[1] The Great Barrier Reef is a young structure in geological terms, having formed during the last 10,000 years of the Holocene epoch; its reefs have always existed in relation to humans, supporting coastal Indigenous subsistence economies and containing many places of cultural and spiritual significance. After European settlement in Australia, the ecosystem influenced the colonial development of Queensland (created a separate British colony in December 1859) and its natural resources were subjected to more intensive exploitation, especially after 1900.

[Take in Figure 1]

European settlement in the area that would become Queensland began in the south-east around Brisbane during the 1820s. The country northwards and inland was rapidly occupied by pastoralists in succeeding decades, with pastoralism emerging as a significant contributor to the Queensland economy by 1900. Many ports (e.g. Port Curtis (later Gladstone); Rockhampton; Port Denison (later Bowen); Townsville) were established to serve the needs of the pastoralists (and later agriculturalists). Port development encouraged the establishment of other industries in coastal Queensland, particularly the tropical districts north of Rockhampton. After 1870, timber getters began removing the red cedar from the tropical rainforests that were found on the Queensland coast between Cooktown and Cardwell. Gold mining was established at several locations (e.g. Cooktown; Charters Towers; Ravenswood; Gympie). In addition, agriculture became significant. Sugar cane became the preferred crop in the tropical and sub-tropical coastal districts by 1900, out-competing all other crops. In the southern Queensland, wheat and maize became the dominant crops, while small farmers pursued dairying.

European interaction with the Great Barrier Reef commenced when mariners realised they needed safe shipping communications with Great Britain. Extensive hydrographic surveying of the Great Barrier Reef and the Queensland coastline was undertaken between 1800 and 1850. During the latter half of the nineteenth century, fishers commenced harvesting the beche-de-mer (or trepang) and pearl- shell from the reefs, while dugongs and turtles were harvested from scattered inshore localities (e.g. Heron Island; Cardwell; Repulse Bay) throughout the Great Barrier Reef. Mining of guano commenced in this period. Between 1900 and 1960, Europeans expanded their

exploitation of the natural resources of the Great Barrier Reef. Mining of coral and phosphate was undertaken in at least a dozen localities. Pearl-shell, trochus shell, dugongs and turtles were harvested to the point where the industries collapsed through over-exploitation. The first tourist resorts were built on several islands (e.g. Green). A nascent reef fishing industry was established. Since 1960, European use of the natural resources of the Great Barrier Reef has been confined to reef fishing, tourism and a regulated coral collecting industry.

Phosphatic sandstone mining at Raine Island, 1844

The need for a safe passage through part of the Great Barrier Reef led to the first significant mining on one of the Reef's islands. Between May and September 1844, a beacon was constructed on Raine Island to assist ship navigators in locating the Blackwood Channel (Lawrence and Cornelius 1993, 1). The beacon was constructed using phosphatic sandstone blocks that were quarried from the eastern part of the island, and lime that was obtained by burning *Tridacna* and *Hippopus* shells; Jukes (1847, 266; see also Lawrence and Cornelius 1993, 4) wrote that the latter were 'to be got in abundance from the reef at low water'. The completed tower comprised a circular tower, 45 feet in height and 30 feet in diameter at its base. The walls were five feet thick, and a domed roof carrying a large ball raised the total height of the structure to 63 feet (Loch 1984, 182). The large size of this structure, on a relatively small island (approximately 850 × 430 metres), suggests that Raine Island sustained a significant geomorphological impact as a result of the quarrying of the phosphatic rock, as Hopley has acknowledged

(Hopley 1982, 337). In addition, the removal of *Tridacna* and *Hippopus spp.* must have occurred on a considerable scale and may have caused localised depletion of those species. These impacts, however, were obscured by the more extensive alteration of the island that took place from 1890-1892 as a result of guano mining.

Guano mining, 1861-1940

Guano, the cemented deposits formed on islands and cays by accumulations of bird droppings, was extracted from the Great Barrier Reef in order to supply phosphatic fertiliser for agriculture. The mining of guano in the Great Barrier Reef has resulted in many changes in islands, which range from minor vegetation modification to the alteration of the geomorphology of entire islands (Hopley 1988, 35). At least nine locations in the Great Barrier Reef have been mined for guano and these locations are shown in Figure 2. A variety of practices occurred in the guano mining industry: some islands and cays, such as Raine Island, were mined intensively with rapid depletion of the commercial resources; other cays, such as Upolu and Michaelmas Cays, were exploited less intensively, but over much longer periods.

[Take in Figure 2]

The date of the earliest guano mining in the Great Barrier Reef is disputed; one account, by Golding (1979, 77-78), stated that the industry was pioneered by William L. Crowther, of Hobart, who applied to the New South Wales Government for licences to

mine guano from Wreck Reef and Cato's Bank in 1861. Golding claimed that, before the permits were issued, Crowther had commenced removing guano from Wreck Reef; one hundred tons of guano had been loaded onto the *Harp* when that boat was shipwrecked on the reef. Informal mining of this type probably took place in the period before the 1860s, when the industry became established, and also in subsequent decades, because control of the industry was hindered by political disputes about the jurisdiction of the offshore islands in the Great Barrier Reef (Cumbrae-Stewart 1930; Foxton 1898, 904).

The first instance of licensed guano mining took place at Lady Elliot Island, from 1863-1873. In 1863, a tender to mine guano from the island by Mr J. Askunas was granted, at a cost of £300 per year; in 1864, Askunas transferred his lease to Crowther, who continued the operation (QNPWS 1999, 5; Walsh, 1987, 30-32). After extraction from the island, the guano was dried, broken down and collected into sheds before being loaded onto barges, and a system of tramways, sheds and moorings for the barges was constructed. The impact of guano mining on the island was severe; a layer more than 2.5 metres thick was removed from the surface of the island and, more than a century later, Hopley (1982, 340; see also Lawrence *et al*. 2002, 20) wrote that little of the original vegetation remained. Heatwole (1984, 39 and 41), similarly, found that the environment of Lady Elliot Island had been significantly disturbed; he stated that most of the vegetation and surface material had been removed by the industry, and 'old diggings, tramways, washing mounds and wells' were still detectable. Indeed, Heatwole (1984, 39 and 41) concluded that 'Lady Elliot Island's prime ecological value is as a reminder of how destructive

uncontrolled human activities can be to a coral cay, and of how prolonged those effects can be.'

After the operation at Lady Elliot Island ceased in 1873, a break occurred in guano mining. However, a decade of further, intensive guano mining took place from 1890-1900. During that period, several other islands were mined in the Capricorn-Bunker Group, and mining also commenced at Raine Island. Previously, during his visit to Raine Island in 1844, Jukes (1847, 266) had commented on the enormous numbers of birds on the island, which produced 'a vast deposit of guano little inferior in quality and value to the famous Peruvian variety'. In 1865, Crowther was issued with a licence to remove guano from Raine Island for seven years; his lease was subsequently transferred to the Anglo-Australian Guano Company and, in 1871, the lease was renewed (Golding 1979, 80 and 82). Some uncertainty exists about whether guano mining took place at Raine Island during the period between the issue of this licence and the commercial operation that commenced in 1890; Loch (1984, 183) claimed that, although leases for guano mining were granted for Raine Island as early as 1862, the island was not mined at that time, because of doubts about the commercial viability of the guano deposits.

While the activities of the earlier period are uncertain, many documentary sources indicate that intensive guano mining took place at Raine Island from 1890-1892. The operations, carried out by J. T. Arundel and Company, under the management of Albert Ellis, employed a large indentured labour force – of approximately 100 Chinese and Malay workers – and ten European supervisors (Lawrence and Cornelius 1993, 5). The

huts, tramway, locomotive and jetty were installed at this time in order to transport ‘tens of thousands of tons of phosphate’ from the island to the ships (Loch 1984, 183; see also Hopley 1988, 34-35. By 1892, however, the mining ceased and the huts, tramway and jetty were removed from the island. A depression, created by the open cast mining, remained in the centre of the island, which is still visible and appears on recent maps, as Figure 3 exemplifies. Hopley (1982, 335 and 337) regarded the damage to Raine Island as probably the most devastating impact on any of the islands of the outer Great Barrier Reef; this island was ‘completely altered’ by the removal of the guano.

[Take in Figure 3]

In addition to the operations at Raine Island, guano mining took place in the Capricorn-Bunker Group of islands, where profound impacts on vegetation were sustained as a result of the industry. During the 1890s, mining was carried out at North Fairfax, North-West and Lady Musgrave Islands, although the degradation caused at each of these islands was less severe than the earlier destruction at Lady Elliot Island; nonetheless, some evidence of guano mining remains in the landscape of these islands (QNPWS 2003, 5-6; see also Marsh 2003, 4). In particular, extensive guano mining occurred at North Fairfax Island; one report by a Queensland National Parks Ranger, written in 1936, stated that the island ‘has been worked very extensively many years ago and large quantities of guano have been removed’ (Anonymous 1936b, 2). The National Parks Ranger also stated that, by 1936, all of the commercially viable guano had been removed, and he reported that the mining had extended over almost the entire island and only a few acres

in the centre of the island remained undisturbed: this central part formed the only section of the island where any vegetation remained, which consisted only of *Pisonia umbellifera*.

One account of guano mining at North Fairfax, North-West and Lady Musgrave Islands was provided by Ellis (1936, 162), which stated that:

> '[North] Fairfax Island was a difficult place to work […]. The phosphate guano too was much mixed with immense quantities of coral slabs and shingle; the large piles of this material left on the island are good evidences as to the amount of labour we put in. Operations on a minor scale were carried on at Lady Musgrave at the same time, a ketch being employed to lighter cargoes across to the sailing vessels loading at the other island. […].
>
> A prospecting trip round the Capricorn Group was carried out on the cutter *Lorna Doone* during 1898. Deposits of medium quality were found on North-West Island. These were worked when Fairfax was finished'.

Of these three islands, particular degradation occurred at North-West Island, which was mined from 1898-1900, as acknowledged in the Management Plan for that island (QNPWS 2003, 5). Golding (1979, 90; see also Lawrence *et al.* 2002, 20) reported that the labour force comprised 107 Asian workers and five Europeans, and the infrastructure included a tramway that was laid across the island and a jetty that was built to the edge of the reef. In November 1899, 550 tons of guano were shipped on the *Van Royal* and another boat – the *Silas* – carried 1,100 tons from the island; Golding stated that, by

February 1900, a total of 4,146 tons of guano had been removed from the island: most of that material was exported to New Zealand (Golding 1979, 90-91). As a result, Heatwole (1984, 28) described North-West Island as 'the most disturbed of the uninhabited islands' in the Capricorn-Bunker Group.

Of the other islands in the Capricorn-Bunker Group, Lady Musgrave Island was worked by guano miners during the 1890s, but little is known about the scale of that operation. Tryon Island was probably mined for guano from 1898-1900, but Heatwole (1984, 28) suggested that those operations must have been small, since few indications of mining remain in the landscape. The National Parks Ranger who visited Hoskyn Island in 1936 reported that 'only a few tons of low grade guano occurred' and, probably, neither of the Hoskyn Islands were mined for guano; in contrast to the higher-grade guano deposits worked at Lady Elliot and North-West Islands, the extraction of material from the Hoskyn Islands was not economically viable. By 1900, the most intensive guano mining had ceased, in Hopley's view, because the commercial resources had been rapidly exhausted (Anonymous 1936b, 3; see also Hopley 1989, 20).

However, guano mining continued after this date at Michaelmas, Oyster and Upolu Cays, near Cairns, in a less intensive manner, but for longer periods (QNPWS 1998). In 1901, Captain Robertson was granted a 21-year lease by the Queensland Government to mine Oyster Cay, 'on which there is a large deposit of guano'; one report claimed that, over the period of his lease, Robertson removed 'over a thousand tons of deposit' from Oyster and Upolu Cays (*The Cairns Morning Post*, 28 May 1901, p. 2; see also Loch 1991, 5). No

evidence was found to indicate that the guano was used to fertilise sugar cane fields on the adjacent Queensland coast, although exports of the product were recorded: for example, to Japan (see, for example, the statistics provided in *SSQ* 1920, 111). The operation raised public concerns about the destruction of the cays; one individual wrote to the Queensland Minister for Mines, asking, 'Could you do anything to prevent Upola Bank [*sic*] and Oyster Cay on the Barrier Reef being destroyed by removing the coral and guano from these banks?' (Dean 1931b). Nevertheless, the mineral leases for these cays were renewed, in 1922, and the removal of guano continued (Loch 1991, 5).

Hence, the impacts sustained in the Great Barrier Reef as a result of guano mining were widespread – occurring in at least nine locations – and prolonged: from 1860 until around 1940. Those impacts also varied in their intensity as different mining strategies were adopted, and as deposits of varying qualities were worked. The earliest instances of guano mining in the Great Barrier Reef were probably informal and unlicensed; however, by the 1860s, the industry had been organised using a system of guano licences and attracted considerable capital investment. The guano at Lady Elliot and Raine Islands was stripped rapidly, and severe geomorphological and ecological transformations occurred at those islands. Bedford (1928) reported that the descendents of domesticated fowls were found on islands that had been worked for guano, since chickens were kept by the miners as a source of food. At Lady Musgrave Island, ridges on the island, resulting from the removal of guano, were visible to Steers in 1937, and at North-West Island, in the same year, Steers (1937, 54 and 65) reported 'noticeable erosion' of the cay that had been exacerbated, he suggested, by the removal of guano. Hopley (1989, 19-20) argued that, at

islands where the geomorphological impacts of guano mining have been severe – especially at Raine, Lady Elliot and North-West Islands – their recovery may take hundreds of years, if in fact those impacts are not irreversible. The history of guano extraction in the Great Barrier Reef, therefore, illustrates the variable nature of early industrial use of that ecosystem and the diverse impacts, rates of recovery, and landscape effects on the cays that were mined.

Rock phosphate mining at Holbourne Island, 1918-1921

By 1918, an alternative source of phosphate to the guano obtained from the cays of the Great Barrier Reef had been discovered: the rock phosphate deposits found on Holbourne Island, near Bowen (*The Bowen Independent*, undated edition of 1941, reprinted in *The Bowen Independent*, 29 January 1971, 4). During the First World War, superphosphate for agricultural fertiliser had been sold in Queensland at a cost of £8 per ton and some investors considered that the Holbourne Island material might form a cheaper source of phosphate. The Holbourne Island Phosphate Co. Ltd. was formed to investigate and work the deposits for the Australian and New Zealand markets; an advertisement for their fertilisers is reproduced in Figure 4. The company took over Holbourne Island Guano Licence No. 1, held previously by Messrs. A. Junner and W. M. Gall, which was reissued as Mineral Leases Nos. 66 and 67, which were in turn replaced by Mineral Lease No. 73 (Saint-Smith 1919, 123). An initial geological survey suggested that around 400,000 tons of phosphate existed on the island. A settlement was constructed on the island, a tramline

was laid, the quarried material was carried to the beach using horses, and the phosphate was transported to barges using punts (Saint-Smith 1919, 122 and 124).

[Take in Figure 4]

Phosphate mining at Holbourne Island commenced in 1918, but the grade of the phosphate was found to be too low to supply inter-state and international markets profitably (Anonymous 1919). However, the material was suitable for local markets, and phosphate was transported from the island, via Bowen, to Brisbane and Townsville for processing. The material was transported in small barge-loads; for example, one record described the import of 25 tons 4 cwt of phosphate to Bowen Harbour by the Australasian Union Steam Navigation Company Limited, in May 1918 (Anonymous 1918). In 1918, a total of 450 tons of material were removed from the island; in 1919, the amount increased to 850 tons. However, in 1920 the annual yield declined to 450 tons, and in 1921 only 369 tons 10 cwt (valued at £1,570) were shipped (Linedale 1922, 600; *The Bowen Independent*, 29 January 1971, 4). Hence, the industry was short-lived and the company ceased operations at the end of 1921. The following factors contributed to the decline of the industry: (a) high production costs due to unreliable shipping; (b) the high cost of freight to the mainland; (c) the lack of drying facilities on the island, increasing the weight of the shipments; (d) labour and provisioning difficulties; (e) the low tonnage output, and (f) a high proportion of lime contained in the Holbourne Island phosphate, which made the cost of manufacturing superphosphate too high, in comparison with other sources (*The Bowen Independent*, 29 January 1971, 4). After 1921, no further working of

phosphate took place at Holbourne Island; subsequently, phosphate was imported from Nauru and Ocean Islands and, in the 1970s, the Holbourne Island deposits were declared not commercially viable. In 1982, Hopley indicated that evidence of the rock phosphate quarry remained in the landscape of Holbourne Island (A.C.F. and Shirleys Fertilizers Ltd. 1950, 2).

Coral mining, 1900-1940

Before coral mining for the manufacture of agricultural lime commenced in the Great Barrier Reef in 1900, lime burning was already an established practice; the earliest recorded instances of Europeans using shells or coral gathered from the Great Barrier Reef to produce lime date from the 1840s. As mentioned earlier, lime for the construction of the navigation beacon at Raine Island was obtained in 1844 by burning *Tridacna* and *Hippopus* shells; and in 1847, at the time of settlement of Port Curtis (now Gladstone), an abundance of shells for lime-burning was reported in the locality (Fitzgerald 1982, 94; Lawrence and Cornelius 1993, 4). Lime was used to make mortar, but burnt coral was also used as a building material in its own right. In 1864, G. Bowen (1864, 116) informed the Royal Geographical Society of London that the creation of a new settlement at Port Albany, Cape York was facilitated by the presence of 'large beds of coral, of the best description for making lime'. In an early description of Queensland, A. J. Boyd (1882, 28) stated: 'The corals bordering our coasts also supply inexhaustible deposits of lime.' By 1900, the church at Fitzroy Island had been built by the Yarrabah Aboriginal Mission using coral taken from the fringing reef at the island. The use of coral as a building

material, therefore, appears to have been an established practice and much larger structures were also constructed using burnt coral, such as the church at Darnley Island (Strelitz 1925). Apart from wood, coral was the most readily available building material for the construction of buildings on islands with fringing reefs, and it could easily be worked.

Throughout the Great Barrier Reef, coral mining took place in order to manufacture agricultural lime for the sugar cane farms on the adjacent coastal land; coral was mined from accessible coral reefs and cays and burnt as a cheap and chemically pure source of lime (Kerr 1995, 92-94; see also Spencer and Meade 1945, 132; King 1965, 104 and 108). Investigations by agricultural scientists from the QBSES in the early 1900s had discovered that the soils of the northern coastal sugar producing districts were very acidic. Acidity is in most instances a result of deficiency of lime in the soil. The function of lime is not merely to neutralise the acid condition. Calcium, the basic ingredient of lime, is an important plant food. Thus lime deficiency means an acid condition, injurious to plant growth, but also a calcium deficiency which slows normal plant development. Thus the agricultural scientists recommended the application of lime in an attempt to increase sugar yields.[2] Burnt lime was also used as a settling agent in the process of manufacturing raw sugar. In 1915-1916, the QBSES reported that, in North Queensland, terrestrial sources of lime were expensive; Ernest Scriven (1915-1916, 1175), the Director of the QBSES, stated:

> ‘The price of lime in Northern sugar districts is still unduly high, and efforts are being made by many of the Farmers’ Associations to open up various lime deposits and also to procure coral lime, coral sand, and shell deposits’.

The following year, Scriven (1916-1917, 1237) reported that interest in coral lime was high and pulverising machines were already on the market. Farmers were advised to use coral fertilisers in combination with green manures and, by 1920, coral lime was being applied in the Mossman, Goondi, Mourilyan and South Johnstone areas at a cost of £3 per ton for coral sand and £4 per ton for burnt coral lime (Scriven 1922, 1034).

Thus, coral mining for agricultural lime commenced in 1900 and continued until at least 1940. During this period, at least twelve coral areas, shown in Figure 5, were mined in the Great Barrier Reef. The earliest account of this activity was written by a shell collector who indicated that the mining of coral reefs occurred at the Barnard Islands around 1900; she stated:

> ‘At the turn of the century last, coral mining was carried out in the Barnard Islands […] and also at the mouth of the Mowbray River: Yule Point. Because of shifting sands and coastal erosion, at times extinct reef is exposed here along the shore. I think the sugar industry used this resource’ (Collins 2003, 1).

Another of the earliest operations took place at Snapper Island, near Cape Tribulation, where Jerry Doyle operated a lime kiln. The kiln was constructed in 1901 by the Mossman Central Mill Company (MCMC), which signed a contract with Jerry Doyle to

provide burnt lime, and he produced ‘ample supplies’ of lime and fertiliser (Kerr 1995, 93; QEPA 2003). The lime kiln was fired using wood from the nearby Daintree rainforest and coral was probably obtained from the accessible and extensive fringing reef on the south-western side of the island; two archival sources describe the track that was cut to allow the firewood to be transported to the lime kiln (Anonymous 1967; QEPA 2003; Rutherford 1967). The company opened a grinding plant to improve the quality of the coral lime, and Doyle’s operation was still in progress in 1911 when the MCMC also entered into a contract for lime with the Chillagoe Railway and Mines Company; subsequently, in 1914, coral mining was carried out by Ishimoto, who was paid £2 per ton by the MCMC to deliver coral lime to the old wharf on the Mossman River (Kerry 1995, 93-94).

[Take in Figure 5]

Another early coral mining operation took place near Innisfail, where E. Garner of Clump Point reported taking coral for agricultural lime from the foreshores of the Barnard Islands in 1900 and from Kings Reef in 1918; these activities pre-dated the introduction of the coral licensing system by the Queensland Government. Garner (1935) reported having difficulty in taking much coral because ‘we can only get on Kings Reef for about two hours at dead low water springs each day’. However, this operation appears to have continued for many years; later, stating that he was too old to continue coral mining, Garner asked for the mining permit to be transferred to his son, Edward Henry Garner, who also operated at a coral area on Kings Reef during the 1930s.

Before 1920, other than Garner's permit, coral mining in the Great Barrier Reef appears to have been unregulated. Oral history evidence indicates that, by 1920, extensive coral mining had taken place at Snapper Island (see Figure 6). (Gray 2003; Roberts 2003; Scomazzon 2003, *passim*). Coral mining at Snapper Island reef may have been continuous since the operation by Jerry Doyle; before the First World War, a German settler – possibly Albert Diehm – operated the lime kiln at Snapper Island and took coral from the fringing reef on the south-western side of the island. One informant, a farmer and spearfisher, who remembered the mining operation, stated, 'I can remember the railway lines across the reef at Snapper Island, on the south-west corner, where the spring is' (Gray 2003, 4). The same informant recalled:

> 'there was a German man there […] until during the First World War, or just before it, and he was mining the coral off the big flats of coral there: it's mostly dead coral. He had a railway line across the reef. He would push out his little trolley, smash the coral off with a crowbar, put it in, wheel it up the reef – or had horses to pull it up – and take it up and burn it in a kiln that he had gouged out of the rocks there – and I think that's still there – chop the trees down on the island to burn them, and cook the coral down into a lime that he supplied to the Mossman Mill for settling their sugar' (Gray 2003, 4-5).

This informant stated that, in the Mossman Mill, the settled mixture was removed as filter mud – or filter press – and spread on the cane fields. He reported that this practice continued until a terrestrial source of lime replaced the use of coral lime as a flocculant.

He believed that the coral mining operation continued until the outbreak of the First World War, when the German settler was interned (Gray 2003, 5-6).

[Take in Figure 6]

Another oral history account, by a retired cane-cutter, indicates that coral mining was carried out at Snapper Island by Jim Tyrie (Roberts 2003, 3). This informant reported that large pieces of coral – that could be lifted by a man – were removed from the fringing reef using crowbars and were loaded into horse-drawn wagons. These wagons were transported to the island along rail tracks that were laid across the fringing reef, parallel to the high water mark, and across the island to the lime kiln. A turntable was installed to transfer the wagons from one rail line to the other. The coral pieces were stored in piles beside the rail track before being burnt in the kiln and crushed; two heaps of coral and the remains of the lime kiln still survive on the island, as Figure 6 shows. The details of the coral mining operation at Snapper Island were described by this informant in the following terms:

> ‘On the south-western face [of Snapper Island…] they had their lime kiln, burning the lime [...]. There was a bloke who used to live over there – this was First World War, somewhere around there, turn of the century […] – and he used to do the burning of the lime. They cleared a big slope of hill for firewood and it’s since grown up again. […] Well, they had a portable tramline, like this tramline here [*indicates a nearby cane track*] […]. The portable rail is only twenty pounds and it will take the same size wheels, so they had small trucks to cart these blocks away.

> There are still two big heaps of them over there that they never got around to burning. And the coral was about two foot […]: some would be a metre long. And there are two big rows of them where they brought them round by boat, put them up there, and the business folded up before they could use them all' (Roberts 2003, 2).

Additional details about the process of removing and burning the coral from the fringing reefs were provided by this informant, who stated:

> They had railway lines to bring the wood down […] and they had the rail there and a turntable would come there [*indicates map*]. They dropped [the coral] into a hole, and they had rail line going there and down the beach. And there are big heaps of coral: a strong man would be able to pick them up and carry them. Of course it was dead coral they got from around the fringing reef […]; and they could go out and bust it open with crowbars, carry it back and put it in [the lime kiln]. […] The heaps of stone are still there and, if you know where to look, you can see the big hole in the side of the hill that they used to tip this wood into, and then put these stones on top so [the coral] would burn, and then they could crush it (Roberts 2003, 2).

The operation at Snapper Island pre-dated the system of coral licences introduced by the QDHM and represents a second example, in addition to Garner's operation at Kings Reef, of unregulated coral mining in the Great Barrier Reef.

The amount of coral taken from the reef is unknown because, as one informant stated, 'he could have taken it from here for years […]. These rails down the beach were there for a

long time after the war, and they disappeared all of a sudden' (Roberts 2003, 3). However, some evidence of the scale of the operation remains in the landscape, as the same informant stated:

> If you went over to look at the heaps of coral, […] you could see the heaps of stone, you could see the incinerator – the place where they burnt it – and you could see the rails, the cutting in the hill and where they had their turntable; because the load came down one angle on a truck, and they'd spin it round and take it this way [*indicates map*] and tip it into the hole. You could see all that (Roberts 2003, 14).

After Tyrie concluded mining at Snapper Island, the informant believed, he moved to the Daintree settlement and sought lime from another source. Another informant suggested that a terrestrial source of lime replaced the material taken from Snapper Island reef after the lime burner ceased operating there; he stated, 'they bought lime from other sources after the bloke on Snapper Island. They started using lime from Chillagoe, which is on the land' (Gray 2003, 6; see also Roberts 2003, 3). The evidence presented above suggests that, by that time, a considerable amount of coral had been removed from Snapper Island reef.

In contrast to the scarcity of documentary evidence for the earlier period, more extensive evidence of coral mining exists for the 1920s. In addition, coral mining operations had become more organised, being based on a system of coral licences. Several individuals were granted licences to remove coral for the production of agricultural lime; the survival of some of these licences makes a more substantial reconstruction of the coral mining

industry possible. The existence of the licences also indicates that, by the 1920s, coral mining was taking place with the encouragement of the Queensland government. In 1922, mineral leases were issued for the removal of coral and coral sand from Green Island and from Oyster and Upolu Cays. The operations were reported to have been significant: one account claims that thousands of tons of material were removed from Upolu Cay; the licence for coral mining at Upolu Cay was re-issued in 1926 and the removal of material from these locations appears to have continued throughout the 1920s until the mid-1930s (Bowen and Bowen 2002, 291; Loch 1991, 5; see also Anonymous 1933, 11). One oral history informant suggested that Upolu Cay had been mined for coral sand by the company, Koppins, although the quantity of coral sand taken was not known (Loch 2003, 10).

Another of the pioneers of coral mining in the Great Barrier Reef was Albert Diehm of Innisfail. In 1927, Diehm was granted a Quarry Licence by the Atherton office of the Queensland Sub-Department of Forestry to remove coral from Hutchinson and Jessie Islands in the Barnard Group. During the following year, he produced lime at Maria Creek, near Innisfail, using coral from those islands. A QDHM memorandum about Diehm's operation stated that:

> 'the crushing works operated by [Albert] Diehm are situated on the Northern end of Hutchinson Island, North Barnard Group, above high-water mark. The plant consists of a Fordson tractor and a disintegrator. The estimated capacity is sixteen tons per day but the estimated daily output is six tons per day' (Aitken 1928).

At the end of 1928, Diehm applied for a Mineral Lease over half an acre of coral on the western side of Hutchinson Island and one-fifth of an acre of coral on the western side of Jessie Island in order to continue his operation (Anonymous 1929).

The initial success of coral mining in northern Queensland attracted the interest of capital investors in southern Australia. In 1928, an article in the *Melbourne Herald* described the industry in the following terms:

> 'There are splendid prospects of a profitable industry in crushing the coral of the Great Barrier Reef for fertiliser. The pioneer of the industry is Mr. Diehm, who recently installed a £500 plant on North Barnard Island, and has already supplied 200 tons of pulverised coral to Innisfail farmers.
>
> Mr. Diehm stated today that one farmer had put twenty tons in his fields and the cane treated has shown an advance of two feet six inches over other cane. […] He intends to bring regular supplies of the fertiliser to Innisfail.
>
> Recently Mr. Diehm obtained additional gear from England and hopes to operate on a larger scale now that pioneering difficulties had been overcome. There were almost unlimited supplies of coral to be drawn on' (*Melbourne Herald*, 24 January 1928, cited in Roskruge 1929).

By mid-1929, Diehm had extracted and crushed coral at Hutchinson Island for at least three years.

Coral was mined not only from islands and cays: it was also removed from inshore coral reefs in the northern Great Barrier Reef, which were more accessible from the mainland and more convenient to work. In 1929, a lease to mine coral at Alexandra Reef, near Port Douglas, was granted to G. Averkoff of Port Douglas who, like Diehm, intended to produce lime for sugar cane fields (Averkoff 1929; Whelan 1929). The location of the coral reefs was between Yule Point and the Mowbray River, and the coral lay 'approximately 5 chains' below high water mark'. As the adjacent land was mangrove swamp and the removal of coral would not interfere with any other industry, the Secretary of the Queensland Marine Board, J. D. W. Dick (1929; see also Kerr 1995, 94), suggested that this application should be granted subject to a royalty of 1d per cubic yard on all coral removed. Averkoff then constructed a lime plant and supplied coral lime to the MCMC for fifteen years, until his operation was taken over by the McDowell Brothers, who continued to deliver the lime to sugar cane farmers.

Several other applications were made to mine coral during the same period. In 1929, High Island, adjacent to the Frankland Group, was the subject of a coral mining application by R. McGuigan, whose application was considered at the same time as those of Diehm; at Pialba, Henry M. Taylor stated that he had access to thousands of tons of coral and claimed the sole right to remove this material using an oil engine (Anonymous 1928). Companies as well as individuals made applications to mine coral. In 1929, Great Barrier Reef Fisheries Ltd. (1929, 5) of Sydney proposed to manufacture 'natural fertilisers obtained from burnt coral'. In the same year, a syndicate of investors in Sydney and Melbourne applied to mine coral and limestone from seven islands in Queensland

waters – including Masthead Island – in order to supply a lime works in Brisbane (Lane 1929). No evidence was found in the QSA to indicate whether or not these leases were granted.

By the late 1920s, therefore, coral mining was regarded as an industry that had the potential to generate significant profits for venture capitalists. In 1928, Edward Sanders (1928a; see also Sanders 1929) of Cooktown applied for leases to dredge coral sand from twelve locations, comprising more than fifty acres, between Mossman and Masthead Island. A syndicate formed by Sanders argued that 100,000 tons of agricultural lime could be used each year in the sugar districts – which they claimed covered 300,000 acres – and that around 10,000 tons of burnt lime were already being used annually by sugar mills, refiners, farmers and builders (Sanders 1928b). The syndicate estimated the demand for agricultural lime to be 8,000 tons per year in Mackay, 8,000 tons per year in Cairns, 10,000 tons per year in Innisfail and 10,000 tons per year for burnt lime; they claimed that, at around £3 per ton, other sources of lime were too expensive for farmers. The syndicate proposed a company to work lime deposits in the Great Barrier Reef 'to supply the cane farmers with a cheap high-grade agricultural lime'; the Queensland Government Agricultural Chemist, J. C. Brunich, supported their proposal, as did Sir Matthew Nathan and the Cane Growers' Associations and Executives of Cairns, Innisfail and Mackay (Sanders *et al.* 1928).

Further expansion of the coral mining industry occurred during the 1930s; more extensive coral mining took place, and the industry was organised using a system of Coral Areas:

reefs and cays that were individually leased and that were considered to be suitable for working. By 1930, applications by at least eight individuals and syndicates for the issue of coral licences were being considered by the Queensland government (Anonymous, 1930). Between 1930 and 1934, leases for five locations were granted to Edward Sanders: for Coral Areas No. 1 Cairns (Oyster Cay), No. 3 Cairns (Sudbury Cay), No. 1 Innisfail (Beaver Reef), No. 1 Mackay (Sandpiper Reef) and No. 1 Townsville (an unnamed sand cay to the north-east of Lucinda). Another coral area at 'Apollo Banks' (Upolu Cay) was leased to Walter Edward Tanner Edward Tanner and Maurice Joseph Kenny of Yungaburra in 1930, whose company – Tanner and Kenny Contractors – applied to dredge for coral lime to produce fertiliser (Forbes 1930; Tanner and Kenny Contractors 1929). Later, in 1934, the lease for the coral area at Hutchinson Reef was extended and the coral leases held by Sanders, with the exception of the site at Oyster Cay, were taken up by Andrew Albert Holland of Sydney (Anonymous 1934; Holland 1933; Holland 1934).

Some concerns were expressed about the advisability of permitting coral mining in the Great Barrier Reef. In addition to public complaints about the destruction of Upolu Cay, the archival sources indicate considerable differences in the opinions of Queensland government officials towards coral mining (Dean 1931a; Dean 1931b). One supporter of the industry, Cullen, the Chief Engineer of the QDHM, discussed the coral mining operation at Upolu Cay, stating that 250 tons of material had been removed from the cay by Tanner and Kenny during the nine-month period from 1 January-30 September 1931. Cullen argued that the public concerns about the destruction of the cay were 'sentimental'

ones and that the resulting disturbance to seabirds – even if this occurred at several cays – could not be regarded seriously. Furthermore, Cullen (1931) stated:

> Assuming (by way of argument) that the cay at which material is being obtained by Messrs Tanner and Kenny was in the course of years entirely removed, it would be because a product of some value was being obtained.

Cullen's view represented a utilitarian perspective towards the resources of the Great Barrier Reef; such a view – in which coral was regarded either as a source of limestone or as a means of promoting tourism – formed the basis of the coral licence system.

In contrast to the view of Cullen, in 1931, the Cairns Town Council (CTC) expressed its concern that the removal of coral from Green Island was threatening the popularity of the island with tourists (Anonymous 1931b). In correspondence with the Queensland Government, the CTC requested legislation to protect Green Island reef from being stripped of its coral, but this request was met with reluctance by the Queensland Treasury because coral mining was 'an industry which the Government considers it advisable to encourage' (Anonymous 1931a). Eventually, the Queensland Government, acknowledging that there was no legal authority by which the reef at Green Island could be placed under the protection of the local Council, issued a licence for the removal of coral from Green Island reef to the CTC; that licence conferred sole rights to removal of coral from Green Island reef on the CTC (Anonymous 1932). Subsequently, in 1937, the Queensland Government did legislate to prohibit the removal of coral from the foreshores and reefs surrounding Green Island, Low Isles, Michaelmas Cay, Arlington Reef and

Oyster Cay; yet the earlier decision to protect Green Island reef was highly significant: it created what was effectively the earliest marine protected area in existence (Lawrence *et al.* 2002, 25).

Nevertheless, the removal of coral continued in other locations in the Great Barrier Reef. From 1936-1938, extensive coral mining took place in the Innisfail area. Edward Henry Garner was granted a lease over Coral Area No. 2 Innisfail (Kings Reef); Thomas Roper held a lease for the adjacent Area No. 5 and also for Areas No. 3 (Hutchinson Island) and No. 4 (Jessie Island) (Hope 1937). Garner reported mining about 70 tons of coral from his site during the quarter ending on 30 June 1935 and 60 tons the following quarter; he also helped to mine Roper's lease. The licences were granted on the condition that explosives would not be used in removing coral; however, the QDHM received complaints that Garner used gelignite to blast coral from the reef before bringing the rubble ashore for burning (Garner 1936; Jones 1973, 317).

In 1939, a syndicate comprising the Villalba Brothers and Martinez and Company applied for leases over Beaver and Taylor Cays, near Dunk Island, and over Coral Area No. 1 Townsville ('Sand Cay Island', to the north-east of Lucinda), in order to collect coral lime (Anonymous 1939). On 7 May 1940, a lease was granted to Martinez, Chapman and Company of Innisfail to remove 1,000 cubic yards of coral from Sand Cay Island; the rights were sold for 3d per cubic yard (Anonymous 1940a). This application indicates the willingness of investors to form syndicates to obtain coral leases and suggests that, by the end of 1930s, coral mining in northern Queensland had become an

established, profitable industry. However, the series of coral licences preserved at the QSA indicates that this lease was the last granted before the outbreak of the Second World War disrupted marine industries in the Great Barrier Reef; during that war, boats were impounded and access to the coral reefs and cays was restricted (Wilson 2003, 2).

No archival evidence was found to indicate if coral mining resumed after the end of the Second World War. The reports of the Queensland Chief Inspector of Fisheries published in the *QPP* indicate that coral and shell-grit licences were issued continuously by the Queensland Government throughout the period from 1930-1968, representing an increasing number of coral licences (see Figure 7). However, these coral licences were also possibly related to the collection of coral for tourism and the aquarium trade. One oral history informant suggested that, after the Second World War, cheaper, terrestrial sources of agricultural lime were used by sugar cane farmers, including lime obtained from Chillagoe and Calcium, near Townsville (Allen 2003, 7). In addition, in 1940, increasing attention was given to the protection of coral reefs in response to the development of tourism in the Cairns, Townsville and Whitsunday regions; the extraction of coral from twenty-eight coral reefs in the Great Barrier Reef was prohibited (Anonymous 1940b). Attempts were made to access additional materials relating to the use of agricultural and industrial lime from sugar industry organisations and informants in Mossman, Gordonvale, Innisfail and Brisbane; those attempts were unsuccessful, either because records managers were uncooperative or because records on the topic did not exist. Therefore, the extent of coral mining between 1945 and 1967, when the proposal to mine coral from Ellison Reef by the Cairns District Canegrowers - an

organisation representing the interests of local canegrowers - was refused by the Queensland Government, is unknown. However, coral mining probably petered out during this period.

[Take in Figure 7]

The earliest indication of the degradation associated with the coral mining industry concerned the works by Tanner and Kenny Contractors at Upolu Cay. In 1931, a complaint about their operation was published in *The Cairns Post*, which stated that Upolu Cay 'was being destroyed by a firm taking away the bank for fertiliser purposes and depriving the sea birds of a home that has been theirs for many years' (Dean 1931a). Material was removed from Upolu Cay by running a tramline into the centre of the cay and quarrying coral to a depth of about four feet (Hamilton 1933a); the tramline and the location of the coral mining area are shown in Figure 8. During the nine months from January-September 1930, Tanner and Kenny Contractors removed 250 tons of material from the cay (Anonymous 1931c). Although their coral licence permitted the removal of coral from the foreshore – below high water mark – Tanner and Kenny had mined the centre of the cay and, by October 1930, the height of the cay had been reduced and almost no bird life or vegetation remained (Brewster 1932).

[Take in Figure 8]

As both Upolu and Oyster Cays had been declared sanctuaries for animal and bird life in 1926, the destruction caused at Upolu Cay provoked objections from naturalists, who were also concerned about the possibility of similar destruction at Oyster Cay. By 1933, Sanders had not yet commenced removing coral from his lease at that site. In spite of public protests, both coral leases were renewed in 1933 (Brewster 1933). By 12 January 1933, Tanner and Kenny had caused further 'serious damage' to Upolu Cay – one report claimed that almost half the cay had disappeared – and continued to disregard the requirement to mine only from the foreshores of the cay (Freeman 1933; Hamilton 1933b; Hamilton 1933c). In addition to the disruption caused to seabirds, the removal of material threatened the stability of the cay and increased its susceptibility to erosion during storms. Finally, in 1934, in response to complaints about the extent of destruction caused by coral mining, the coral licences for both Upolu and Oyster Cays were revoked by the QDHM (Bowen and Bowen 2002, 291).

Other evidence of the destruction caused by coral mining exists for Kings Reef, near Innisfail, where the operation carried out by Garner also elicited complaints. Several reports claimed that the nearby bathing beach at Murdering Point had become unusable as a result of sharp pieces of coral being washed ashore after Garner's blasting operations. One of these reports stated that:

> 'Garner is in the habit of using explosives to loosen the coral from the reef, which when broken off he leaves in heaps. The prevailing weather and currents set in from where he is blasting towards Murdering Point beach, and the result is that sharp and

> light pieces of coral are washed in and are a danger to persons using the beach [...]. The pieces of coral also cut fishing nets used by the fishermen at the beach. After any boisterous weather there is always a fair amount of coral washed in to the beach, and even in fine weather a good deal of it comes in' (Donovan 1935; see also Anonymous 1936a).

The use of explosives by Garner was also blamed for driving fish away from the area: another concern for the fishers besides damage to their nets. On the miners themselves, the blasted coral inflicted skin burns and large 'coral sores' that resembled ulcers (Jones 1973, 317).

No other documentary evidence of the destruction of coral reefs and cays as a result of coral mining was found in the archival sources. Hence, the remaining environmental impacts of coral mining can only be estimated. The inshore coral reefs, which were the most accessible mining locations, probably suffered the most sustained and destructive impacts of coral mining; Kings Reef and Alexandra Reef are the reefs most likely to have been extensively degraded, since they were worked from a comparatively early date – before 1930 – and were easily reached from the coast. Today, both reefs appear to be almost completely degraded: the reef flat at Kings Reef is characterised by coral rubble, soft corals, mud and algae and lacks extensive hard coral communities; the surface of Alexandra Reef, shown in Figure 9, comprises dead coral, with living colonies found only at the submerged edges of the reef (Hopley 2003, 6). While the dead coral found at these reefs cannot be attributed solely to coral mining, the blasting and removal of coral has probably contributed to their degradation.

[Take in Figure 9]

Oral history evidence suggests that the impacts of coral mining were extensive at Snapper Island reef and large mounds of mined, unburnt coral still exist on the island near the remains of the lime kiln. In addition to the removal of coral from the reef flat using crowbars, the coral cover was probably diminished by trampling of horses and the construction of rail lines across the surface of the reef (Gray 2003, 4-6; Roberts 2003, 2-3 and 17). While Snapper Island was less accessible than the inshore reefs at Kings and Alexandra Reefs, a dwelling was built on the island, which enabled more sustained mining to take place than on the uninhabited cays. In common with other inshore and fringing reefs, Snapper Island reef was particularly vulnerable to human impacts. However, unlike Kings and Alexandra Reefs, in the 1990s, Snapper Island reef contained a very large cover and diversity of living corals, as one oral history informant – a marine biologist – reported. Consequently, the discernable impacts of coral mining are now probably more apparent in the landscape of the island than in the fringing reef (Ayling 2003, 8).

This account of coral mining, however, is incomplete as a result of gaps in the archival records, the difficulty in obtaining original oral histories for the period before 1940, and the lack of extensive scientific monitoring of the Great Barrier Reef before 1970. The sequence of surviving records of coral areas – which includes Coral Areas No. 1 (Cairns) and No. 3 (Cairns), but not No. 2 (Cairns) – suggests that more locations were mined than

are mentioned here. Furthermore, other instances of unlicensed coral mining may have taken place that are not mentioned in the documentary record, just as extensive operations took place at Snapper Island without, apparently, any documentary evidence surviving in the records of the QDHM that were consulted at the QSA. Therefore, this account gives an overview of what may have been a more extensive industry in the Great Barrier Reef. At these locations, coral mining may have caused significant changes in parts of several reefs of the Great Barrier Reef; implications of those changes for the management of the GBRWHA are discussed below.

Implications for contemporary management

The extraction of mineral resources from islands of the Great Barrier Reef persisted for almost a century and affected at least ten islands; those impacts ranged from the removal of thousands of tons of guano (at their most benign) to the complete alteration of the geomorphology of the cays (at their most extreme). At Raine and Lady Elliot Islands, the impacts of guano mining remain in the landscape; at Lady Musgrave Island, those landscape impacts became visible when as a result of another impact – over-grazing by introduced goats – the surface of that cay was exposed. Another substantial change to the geomorphology of an island occurred at Holbourne Island, by 1922, as a consequence of the extraction of rock phosphate, where the location of the quarry can still be identified in the landscape (Hopley 1982, 376). In addition, as a result of the coral mining industry, between 1900 and 1940, at least twelve coral reefs were modified and thousands of tons of coral were removed from some areas: particularly at Snapper Island, Upolu Cay, the

North Barnard Islands, and Kings Reef. Several of these reefs – especially Kings and Alexandra Reefs – now appear highly degraded. Furthermore, all of the coral mining locations described above may have become more vulnerable to other impacts, including natural changes, and experienced a reduced capacity to recover from other environmental stresses as a result of coral mining. The twelve coral mining sites reconstructed here may require complete protection from other impacts if they are to achieve conditions similar to those that existed before this industry began – or are to be resilient to the effects of climate change.

The impacts of coral mining in the Great Barrier Reef have not yet been the subject of scientific investigation, although some impacts of coral mining have been documented for other coral reefs. Gomez, for example, referred to the removal of large quantities of coral from Pacific Island reefs – in a largely uncontrolled and unmonitored manner – for construction purposes. In particular, Gomez (1982-1983, 283 and 288-289) referred to the destruction of '*Porites* and *Goniopora* which are sawed into tiles for use in buildings' in the Philippines, and provided the following description of coral mining impacts:

> In Indonesia, corals are used in the construction of jetties, walls, fishing weirs, roads, and are burned as a source of lime […]. Coral mining is believed to have caused the reduction in size to about one-half the original of the coral islands Ubi Besar and Niwana […]. In Bali, the collection of corals for lime has resulted in serious environmental degradation […]. Extensive coral mining has also been cited as a problem in the Spermonde Archipelago. The use of corals as building materials occurs in many coastal towns in Malaysia […]. The extent of damage to reefs in

> Sabah inflicted by such an activity was estimated to be a loss in the order of 6.8 km of reef front per year […]. In Papua New Guinea, the deterioration of reefs around Rabaul is attributed to the collection of corals for lime […].

Additional evidence of the impacts of coral mining was provided by Soekarno (1989, 217), who stated that records of historical coral mining in the Seribu Islands, in the Java Sea, indicate that between 8,500 and 25,000 cubic metres of coral were mined annually during the early twentieth century, and that the rate of extraction had since escalated. Soekarno (1989, 217) also stated that the most severe coral mining in the Bay of Jakarta occurred around the islands of Air Kecil and Ubi Kecil where, as 'a result of subsequent erosion both islands have now disappeared.' These studies indicate that considerable, permanent impacts on coral reefs can result from coral mining.

Hughes *et al.* (2005, 3) have argued that a wealth of archaeological and historical information about the profound transformations of marine ecosystems resulting from human activities has been largely ignored in contemporary environmental management. Those authors stated:

> 'Marine ecosystems exhibit varying degrees of hysteresis – their recovery follows a different trajectory from that observed during decline. Some systems have changed to the extent that they can effectively no longer converge to the original assemblage. From a complex systems perspective, they have crossed a threshold into a new state or domain of attraction that precludes return to the original state. The implications for

> management are profound: it is easier to sustain a resilient ecosystem than to repair it after a phase shift has occurred'. (Hughes *et al.* 2005, 3)

Such comments may well apply to the twelve coral mining locations of the Great Barrier Reef; furthermore, as Hughes *et al.* (2005, 2) acknowledged, ecologists increasingly on the 'cumulative and interactive effects of sequences of events, rather than concentrating solely on the most recent insult that leads to ecosystem collapse'. In the context of the recent deterioration of the GBRWHA, coral mining represents one of many pressures that may have caused some reefs to experience such a phase shift beyond which recovery to their former state may be extremely unlikely.

Conclusions

We have presented evidence of considerable mining activity in the Great Barrier Reef spanning almost a century, from 1844 to 1940, and focused on four types of industry: phosphatic sandstone, guano, rock phosphate and coral mining. Each type has marked specific environments of the Great Barrier Reef in particular ways. The prolonged period of guano mining at Upolu, Oyster and Michaelmas Cays, from 1901 to 1940, for instance, contrasted with the intensive plunder of phosphatic sandstone and guano from Raine Island in 1844 and from 1892 to 1900, the exploitation of Lady Musgrave Island between 1863 and 1873, and the extraction of rock phosphate from Holbourne Island from 1918 to 1921. Considerable variability also existed in the coral mining industry, with parts of some reefs (especially Snapper, Upolu, North Barnard and Kings Reefs) being intensively mined and, most likely, dramatically modified. Since GBRWHA is the largest

coral reef complex in the world and has been protected as a result of its 'superlative natural phenomena', the condition of the coral reefs of the Great Barrier Reef is of critical importance (UNESCO 1980, 22-23). In addition, because the dates and locations of coral mining have been established with relative precision, these sites could also be used as test sites for scientific monitoring the recovery of coral reefs from mining, if suitable control sites can be identified. Thus these sites may function as valuable indicators of coral reef resilience or vulnerability. In any case, the extent of historical mining in the Great Barrier Reef suggests the importance of 'assessing and actively managing resilience' and maintaining effective marine no-take areas (NTAs) in the GBRWHA, in which all extractive industry is prohibited (Bellwood *et al.* 2004, 831; Hughes *et al.* 2005, 2). Hence, these findings support the claim by Bellwood *et al.* (2004, 831) for a range of 'more vigorous, innovative and adaptive management strategies'.

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References

A.C.F. and Shirleys Fertilizers Ltd. 1950, In-letter to Secretary, Cairns Harbour Board, Cairns, 19 July 1950, RSI13111/1 Item 84, Batches, Harbour Board – Cairns – Leases to ACF and Shirleys, QSA.

Aitken, A. E. 1928, Memo Ref. 1159, Harbour Master, Innisfail to Port Master, Queensland Marine Department, Brisbane, 12 March 1928, PRV8340/1 Item 1, QSA.

Allen, B. and Montell, W. L. 1981, *From memory to history: using oral sources in local historical research*, Nashville, Tennessee, The American Association for State and Local History.

Anonymous 1918, Harbour Board, Bowen, Statistical Book No. 1, July 1915 – February 1926, RSI5551/1 Item 1, Statistical books, QSA.

Anonymous 1919, 'Shipment of phosphates', *The Bowen Independent*, 22 February 1919.

Anonymous 1928, 'Application to remove coral'; Out-letter Ref. 28/7419, Queensland Marine Department, Brisbane to Chief Engineer, Queensland Harbours and Rivers Department, Brisbane, 24 April 1928, PRV8340/1 Item 1, QSA.

Anonymous 1929, 'Application to remove coral, etc. from islands and Barrier Reef', 1929, PRV8340/1 Item 1, QSA.

Anonymous 1930, 'Regulations governing the taking of coral or shell-grit – Section 18 of *The Fish and Oyster Act of 1914*', PRV8340/1 Item 1, QSA .

Anonymous 1931a, In-letter Ref. L.A.C.T. Gen., Under-Secretary, Queensland Treasury, Brisbane to Town Clerk, Cairns, 22 January 1931, SRS146/1 Item 2, QSA.

Anonymous 1931b, In-letter, Town Clerk, Cairns to Queensland Marine Board Office, Brisbane, 21 August 1931, SRS146/1 Item 2, QSA.

Anonymous 1931c, Out-letter Ref. 31/9363, Chief Engineer, QDHM, Brisbane to Under-Secretary, Queensland Treasury, Brisbane, 19 November 1931, PRV8340/1 Item 1, QSA.

Anonymous 1932, In-letter, Under-Secretary, Queensland Treasury, Brisbane to Town Clerk, Cairns, 20 April 1932, SRS146/1 Item 2, QSA.

Anonymous 1934, Out-letter, Chief Inspector of Fisheries, QDHM, Brisbane to Harbour Master, Mackay, 5 October 1934, PRV8340/1 Item 1, QSA.

Anonymous 1936a, In-letter Ref. 6174, Inspector of Fisheries, Innisfail to Chief Inspector of Fisheries, QDHM, Brisbane, 10 August 1936, SRS31/1 Box 13, QSA.

Anonymous 1936b, In-letter Ref. 225/2, National Parks Ranger to Secretary, 6 October 1936, SRS5416/1 Box 9 Item 57, NP224, Bunker – Lady Musgrave Island, QSA.

Anonymous 1937, 'Great Barrier Reef: supplies of coral sand', *The Cairns Post*, 16 January 1933, 11.

Anonymous 1939, Out-letter, Secretary, Provisional Administration Board, QDHM to Secretary, Land Administration Board, Queensland Department of Public Lands, Brisbane, 31 July 1939, SRS31/1 Box 13/1, QSA.

Anonymous 1940a, In-letter Ref. 225/47, Secretary, Queensland Forest Service, Queensland Forestry Sub- Department, Brisbane to Secretary, QDHM, Brisbane, 26 July 1940, SRS31/1 Box 13/1, QSA.

Anonymous 1940b, Letter Ref. 4868, Secretary, QDHM, Brisbane to Secretary, Queensland Sub- Department of Forestry, Brisbane, 29 October 1940, PRV8340/1 Item 1, QSA.

Anonymous 1967, In-letter Ref. AWG:LDM, District Forester, Atherton to Secretary, Queensland Department of Forestry, Brisbane, 19 May 1967, SRS5146/1, NP64, Snapper Island, QSA.

Averkoff, G. 1929, In-letter Ref. 47990, G. Averkoff, Port Douglas to Harbour Master, Port Douglas, 27 September 1929, PRV8340/1 Item 1, QSA.

Ayling, A. 2003, Oral History Interview, OHC 20, 9 September 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Bedford, R. 1928, *The Great Barrier Reef: a series of photographs by E. F. Pollock and Frank Hurley*, Sydney, Art in Australia.

Bellwood, D. R., Hughes, T. P., Folke, C. and Nyström, M. 2004, 'Confronting the coral reef crisis', *Nature*, Vol. 429, 24 June 2004, 827-833.

Bowen, G. 1864, 'Containing reports upon the formation of a new settlement at Cape York, at the northernmost point of the Australian continent; and upon the completion of the survey of the inside of the Great Barrier Reef, off the north-east coast, by Commander Robinson, R.N.', *Proceedings of the Royal Geographical Society of London*, Session 1863-1864, Vol. 8, No. 4, 114-118.

Bowen, J. 1994, 'The Great Barrier Reef: towards conservation and management', in S. Dovers (ed), *Australian environmental history: essays and cases*, Melbourne, Oxford University Press, 234-256.

Bowen, J. and Bowen, M. 2002, *The Great Barrier Reef: history, science, heritage*, Cambridge, Cambridge University Press.

Boyd, A. J. 1882, *Queensland*, Queensland Government Emigration Office, London.

Brewster, J. 1932, In-letter Ref. 0316, Harbour Master, Cairns to Port Master, Brisbane, 16 January 1932, PRV8340/1 Item 1, QSA.

Brewster, J. 1933, In-letter Ref. 0316, Harbour Master, Cairns to Land Agent, District Land Office, Cairns, 30 August 1933, PRV8340/1 Item 1, QSA.

Carruthers, D. S. 1969, 'Limestone mining', in *The future of the Great Barrier Reef: papers of an Australian Conservation Foundation symposium, Sydney, 3 May 1969*, comp. Australian Conservation Foundation, Parkville, Victoria, Australian Conservation Foundation, 47-50.

Collins, B. 2003, 'Recollections of the reef', Unpublished Report, *Changes in the Great Barrier Reef since European Settlement*, Oral History Collection, School of TESAG, James Cook University, September 2003, 1-2.

Commonwealth of Australia, Productivity Commission 2003, *Industries, land use and water quality in the Great Barrier Reef catchment*, Research Report, Canberra, Commonwealth of Australia Productivity Commission.

Cronon, W. 1990, 'Modes of prophecy and production: placing nature in history'. *Journal of American History*, Vol. 76, No. 4, 1122-1131.

Cullen, A. 1931, Out-letter Ref. 31/9363, Chief Engineer, QDHM, Brisbane to Under-Secretary, Queensland Treasury, Brisbane, 19 November 1931, PRV8340/1 Item 1, QSA.

Cumbrae-Stewart, F. W. S. 1930, *The Boundaries of Queensland: with special reference to the maritime boundary and the* Territorial Waters Jurisdiction Act, 1878, Government Printer, Brisbane.

Dean, F. H. 1931a, 'Correspondence: destroying Upola Bank on Barrier Reef', *The Cairns Post*, 27 October 1931, 11.

Dean, F. H. 1931b, In-letter, Mr. F. H. Dean, Kuranda to Mr. Atherton, Minister, Queensland Department of Mines, Brisbane, 20 November 1931, PRV8340/1 Item 1, QSA.

Demeritt, D. 1994, 'Ecology, objectivity and critique in writings on nature and human societies', *Journal of Historical Geography*, Vol. 20, No. 1, 22-37.

Dennis, P. 2003, Oral History Interview, OHC 36, 28 October 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Denzin, N. K. and Lincoln, Y. S. 2000, 'Introduction: the discipline and practice of qualitative research', in N. K. Denzin and Y. S. Lincoln (eds), *Handbook of qualitative research*, 2nd edition, Thousand Oaks, California, Sage Publications, 1-28.

Dick, J. D. W. 1929, Out-letter Ref. 29/9270T, Secretary, Queensland Marine Board Office, Brisbane to Under-Secretary, Queensland Treasury, Brisbane, 29 October 1929, PRV8340/1 Item 1, QSA.

Donovan, F. R. 1935, In-letter, Constable F. R. Donovan, Silkwood to Police Magistrate, Innisfail, 13 July 1935, SRS31/1 Box 13/1, QSA.

Ellis, A. F. 1936, *Adventuring in coral seas*, Sydney, Angus and Robertson.

Endean, R. 1982, *Australia's Great Barrier Reef*, St. Lucia, Queensland, University of Queensland Press.

Fitzgerald, R. 1982, *From the Dreaming to 1915: a history of Queensland*, St. Lucia, Queensland, University of Queensland Press.

Forbes 1930, In-letter Ref. 30/6493, Forbes, for Under-Secretary, Brisbane to Chief Inspector of Fisheries, QDHM, Brisbane, 13 November 1930, PRV8340/1 Item 1, QSA.

Foxton, J. F. G. 1898, '*The Land Act, 1897*, and *The Pastoral Leases Act of 1869*', *QVP*, Vol. 3, Part 2, 903-906, 904.

Freeman, H. J. 1933, In-letter, Instructor in Fruit Culture to Under-Secretary, Queensland Department of Agriculture and Stock, Brisbane, 12 September 1933, PRV8340/1 Item 1, QSA.

Furnas, M. 2003, *Catchments and corals: terrestrial runoff to the Great Barrier Reef*, Townsville, AIMS.

Garner, E. H. 1935, In-letter Ref. 0663, Mr. E. H. Garner, Clump Point to Mr. W. V. B. Forrester, Port Master, 23 January 1935, PRV8340/1 Item 1, QSA.

Garner, E. H. 1936, In-letter Ref. 0991, Mr. E. H. Garner, Clump Point to Inspector of Fisheries, Innisfail, 29 January 1936, SRS31/1 Box 13/1, QSA.

Gillham, B. 2000, *The research interview*, London, Continuum.

Golding, W. R. 1979, *Beyond horizons*, Wholesale Book and Library Suppliers, Brisbane.

Gomez, E. D. 1982-1983, 'Perspectives on coral reef research and management in the Pacific', *Ocean Management*, Vol. 8, 281-295.

Gray, D. 2003, Oral History Interview, OHC 16, 2 September 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Great Barrier Reef Fisheries Ltd. 1929, *Tapping the wealth of the Great Barrier Reef*, Great Barrier Reef Fisheries Ltd., Sydney.

Hamilton, C. J. 1933a, In-letter Ref. 33/3117, C. J. Hamilton, Land Agent and Deputy Land Commissioner, Cairns to Secretary, Land Administration Board, Brisbane, 19 January 1933, PRV8340/1 Item 1, QSA.

Hamilton, C. J. 1933b, In-letter, C. J. Hamilton, Land Agent, District Land Office, Cairns to Secretary, North Queensland Naturalists' Club, Cairns, 7 September 1933, PRV8340/1 Item 1, QSA.

Hamilton, C. J. 1933c, In-letter, C. J. Hamilton, Land Agent, District Land Office, Cairns to Mr. H. F. Todd, Assistant Secretary, Great Barrier Reef Committee, 28 September 1933, PRV8340/1 Item 1, QSA.

Heatwole, H. 1984, 'The cays of the Capricornia Section, Great Barrier Reef Marine Park, and a history of research on their terrestrial biota', in W. T. Ward and P. Saenger (eds), *The Capricornia Section of the Great Barrier Reef: Past, present and future*, Brisbane, The Royal Society of Queensland and ACRS, 25-44.

Hoegh-Guldberg, O. 1999, *Climate change, coral bleaching, and the future of the world's coral reefs*, viewed 2 October 2003, <www.greenpeace.org.au/climate/pdfs/coral_report.pdf>

Holland, A. A. 1933, In-letter Ref. 33/5239, Mr. A. A. Holland to Chief Inspector of Fisheries, QDHM, Brisbane, PRV8340/1 Item 1, QSA.

Holland, A. A. 1934, In-letter Ref. 6699, Mr. A. A. Holland, Sydney to Chief Inspector of Fisheries, QDHM, Brisbane, 30 October 1934, PRV8340/1 Item 1, QSA.

Hope, T. G. 1937, In-letter Ref. 37/4439, Thos. G. Hope, Acting Under-Secretary, Queensland Treasury to the Official Secretary to His Excellency the Lieutenant Governor, Brisbane, 8 July 1937, SRS31/1 Box 13, QSA.

Hopley, D. 1982, *The geomorphology of the Great Barrier Reef: Quaternary development of coral reefs*, New York, John Wiley and Sons.

Hopley, D. 1988, 'Anthropogenic influences on Australia's Great Barrier Reef', *Australian Geographer*, Vol. 19, No. 1, 26-45.

Hopley, D. 1989, *The Great Barrier Reef: ecology and management*, Melbourne, Longman Cheshire.

Hopley, D. 2003, Oral History Interview, OHC 35, 20 October 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J. B. C., Kleypas, J., Lough, J. M., Marshall, P., Nyström, M., Palumbi, S. R., Pandolfi, J., Rosen, B. and Roughgarden, J. 2003, 'Climate change, human impacts, and the resilience of coral reefs', *Science*, Vol. 301, 15 August 2003, 929-933.

Hughes, T. P., Bellwood, D. R., Folke, C., Steneck, R. and Wilson, J. 2005, 'New paradigms for supporting the resilience of marine ecosystems', Article submitted to *Trends in Ecology and Evolution*.

Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., Bradbury, R. H., Cooke, R., Erlandson, J., Estes, J. A., Hughes, T. P., Kidwell, S., Lange, C. B., Lenihan, H. S., Pandolfi, J. M., Peterson, C. H., Steneck, R. S., Tegner, M. J. and Warner, R. R. 2001, 'Historical overfishing and the recent collapse of coastal ecosystems', *Science*, Vol. 293, 27 July 2001, 629-638.

Jones, D. 1973, *Hurricane lamps and blue umbrellas: a history of the Shire of Johnstone to 1973*, The Cairns Post Pty. Ltd., Cairns.

Jukes, J. B. 1847, *Narrative of the surveying voyage of H.M.S. Fly*, Vol. 2, T. and W. Boone, London.

Kelleher, G. 2003, Oral History Interview, OHC 14, 26 August 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Kerr, J. 1995, *Northern outpost*, 2nd edn, Mossman Central Mill Co., Mossman.

King, N. J. 1965, 'Soil acidity and liming', in N. J. King, R. W. Mungomery and C. G. Hughes (eds), *Manual of cane-growing*, rev. and enlarged edn, Angus and Robertson, Sydney, 99-109.

Lane, J. E. 1929, In-letter, J. E. Lane, Brisbane to Secretary, Queensland Provisional Forestry Board, 18 October 1929, PRV8340/1 Item 1, QSA.

Lawrence, D. and Cornelius, J. 1993, 'History, relics and tower graffiti', in A. K. Smyth *et al*. (eds), *Raine Island and environs Great Barrier Reef: quest to preserve a fragile outpost of nature*, Raine Island Corporation/GBRMPA, Brisbane, 1-11.

Lawrence, D., Kenchington, R. and Woodley, S. 2002, *The Great Barrier Reef: finding the right balance*, Carlton South, Victoria, Melbourne University Press.

Limpus, C. J. 1978, 'The Reef: uncertain land of plenty', in H. J. Lavery (ed), *Exploration north: a natural history of Queensland*, rev. edn., Lloyd O'Neil, South Yarra, 187-222.

Linedale, J. C. 1922, 'Warden's report on gold and mineral fields for 1921', *QPP*, Vol. 2, pp. 599-604.

Loch, I. 1984, 'Raine Island: a foul hen roost', *Australian Natural History*, Vol. 1, Part 5, Winter 1984, 181-183.

Loch, I. 1991, 'Michaelmas Cay', *Cairns Shell News*, Vol. 11, p. 5.

Loch, I. 2003, Oral History Interview, OHC 15, 27 August 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Lough, J. M. 1999, *Sea surface temperatures on the Great Barrier Reef: a contribution to the study of coral bleaching*, Research Publication No. 57, Townsville, GBRMPA.

Marsh, H. 2003, Oral History Interview, OHC 44, 4 December 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

McCulloch, M., Fallon, S., Wyndham, T., Hendy, E., Lough, J. and Barnes, D. 2003, 'Coral record of increased sediment flux to the inner Great Barrier Reef since European settlement', *Nature*, Vol. 421, 13 February 2003, 727-730.

Pandolfi, J. M., Bradbury, R., Sala, E., Hughes, T. P., Bjorndal, K. A., Cooke, R. G., McArdle, D., McClenachen, L., Newman, M. J. H., Paredes, G., Warner, R. R. and Jackson, J. B. C. 2003, 'Global trajectories of the long-term decline of coral reef ecosystems', *Science*, Vol. 301, 957.

Pandolfi, J. M., Jackson, J. B. C., Baron, N., Bradbury, R. H., Guzman, H. M., Hughes, T. P., Kappel, C. V., Micheli, F., Ogden, J. C., Possingham, H. P. and Sala, E. 2005, 'Are U.S. coral reefs on the slippery road to slime?', *Science*, Vol. 307, 18 March 2005, 1725-1726.

QEPA (Queensland Environmental Protection Agency) 2003, *Visitor information: Snapper Island NP and Marine Park,* QEPA, Brisbane.

Queensland Government, Science Panel (Great Barrier Reef Protection Interdepartmental Committee Science Panel) 2003, *A report on the study of land-sourced pollutants and their impacts on water quality in and adjacent to the Great Barrier Reef*, viewed 30 January 2003, <www.premiers.qld.gov.au/about/reefwater.pdf>

QNPWS (Queensland National Parks and Wildlife Service) 1998, *Michaelmas and Upolu Cays National Park Management Plan*, QNPWS, Brisbane.

QNPWS 1999, *Capricornia Cays National Park Management Plan*, QNPWS, Brisbane.

Roberts, M. 2003, Oral History Interview, OHC 17, 2 September 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Robertson, B. M. 2000, *Oral history handbook*, 4th edition, Adelaide, Oral History Association of Australia (South Australia Branch) Inc.

Roskruge, N. G. 1929, Out-letter, Deputy Director, Navigation and Lighthouses, Queensland Marine Branch (Navigations and Lights Services), Brisbane to Dr. Marks, Honorary Secretary, Great Barrier Reef Committee, Brisbane, 20 July 1929, PRV8340/1 Item 1, QSA.

Rutherford, W. L. 1967, In-letter Ref. AWG:LDM, William L. Rutherford, Port Douglas to District Forester, Atherton, 11 May 1967, SRS5146/1 Box 2 Item 10, NP64, Snapper Island, QSA.

Saint-Smith, E. C. 1919, 'Geological survey report: rock phosphate deposit on Holbourne Island, near Bowen', *Queensland Government Mining Journal*, Vol. 20, 15 March 1919, pp. 122-124.

Sanders, E. 1928a, In-letter, E. Sanders to Honorary Minister for Mines, Brisbane, 22 March 1928, PRV8340/1 Item 1, QSA.

Sanders, E. 1928b, In-letter, E. Sanders to Honorary Minister for Mines, Brisbane, 15 August 1928, PRV8340/1 Item 1, QSA.

Sanders, E. 1929, In-letter, E. Sanders to Honorary Minister for Mines, Brisbane, 4 April 1929, PRV8340/1 Item 1, QSA.

Sanders, E., Pritchard, G. H., Campbell, J. G. and Jones, T. L. 1928, In-letter, Messrs. E. Sanders and others' syndicate (E. Sanders, G. H. Pritchard, Jas. G. Campbell and T.

L. Jones) to Honorary A. J. Jones, Minister for Mines, Brisbane, 7 December 1928, PRV8340/1 Item 1, QSA.

Scomazzon, B. 2003, Oral History Interview, OHC 28, 19 September 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

Scriven, E. 1915-1916, Annual Report, QBSES, 1914-15, *QPP*, Vol. 2, p. 1175.

Scriven, E. 1916-1917, Annual Report, QBSES, 1915-16, *QPP*, Vol. 2, p. 1237.

Scriven, E. 1922, Annual Report, QBSES, 1920-21, *QPP*, Vol. 2, p. 1034.

Soekarno, R. 1989, 'Comparative studies on the status of Indonesian coral reefs', *Netherlands Journal of Sea Research*, Vol. 23, No. 2, 215-222.

Spencer, G. L. and Meade, G. P. 1945, *Cane sugar handbook: a manual for cane sugar manufacturers and their chemists*, 8th edn., John Wiley and Sons, Inc., New York.

Steers, J. A. 1937, 'Detailed notes on the islands surveyed and examined by the geographical expedition to the Great Barrier Reef in 1936', *Reports of the Great Barrier Reef Committee*, Vol. 4, Part 3, No. 7, 51-104.

Strelitz, N. R. 1925, 'Trojan car trip, 1925, from Thursday Island to Pascoe River, Cape York, showing coral church (All Saints), Darnley Island', Image No. P02139, Image Library, Cairns Historical Society, Cairns.

Tanner and Kenny Contractors 1929, In-letter Ref. 29/2120, Tanner and Kenny Contractors to Secretary, Queensland Department of Mines, Brisbane, 5 August 1929, PRV8340/1 Item 1, QSA.

UNESCO (United Nations Educational, Scientific and Cultural Organisation) 1980, *The World Heritage Convention*, UNESCO, Paris.

Walsh, A. 1987, *Lady Elliot: first island of the Great Barrier Reef*, Boolarong Publications, Brisbane.

Whelan, E. J. 1929, In-letter Ref. 47990, E. J. Whelan, Harbour Master, Port Douglas to Chief Inspector of Fisheries, QDHM, Brisbane, 1 October 1929, PRV8340/1 Item 1, QSA.

Williams, M. 1994, 'The relations of environmental history and historical geography', *Journal of Historical Geography*, Vol. 20, No. 1, 3-21.

Williams, D. McB. 2001, *Impacts of terrestrial run-off on the Great Barrier Reef World Heritage Area*, Report to CRC Reef, Townsville, CRC Reef Research Centre.

Williams, D. McB., Roth, C. H., Reichelt, R., Ridd, P., Rayment, G. E., Larcombe, P., Brodie, J., Pearson, R., Wilkinson, C., Talbot, F., Furnas, M., Fabricius, K., McCook, L., Hughes, T., Hoegh-Guldberg, O. and Done, T. 2002, *The current level of scientific understanding on impacts of terrestrial run-off on the Great Barrier Reef World Heritage Area*, Consensus Statement, Townsville, CRC Reef Research Centre, 1-2.

Wilson, F. 2003, Oral History Interview, OHC 42, 13 November 2003, *Changes in the Great Barrier Reef since European Settlement*, Oral History Cassettes Nos. 1-47, October 2002-December 2003, School of TESAG, James Cook University, Cairns.

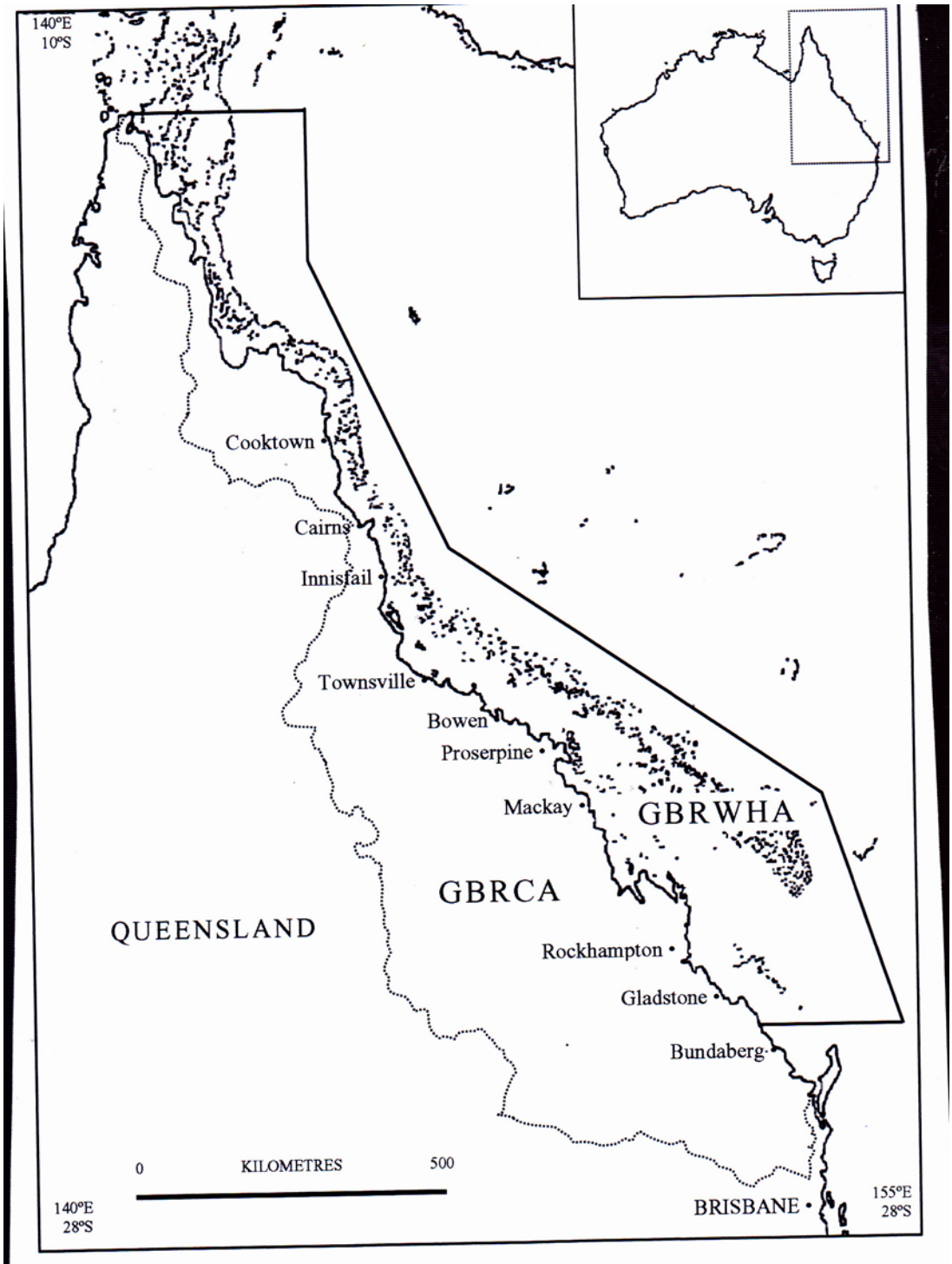

FIGURE 1. The geographical extent of the Great Barrier Reef World Heritage Area (GBRWHA) and the Great Barrier Reef Catchment Area (GBRCA).

Source: Based on Miles Furnas, *Catchments and Corals: Terrestrial Runoff to the Great Barrier Reef* (Townsville, Australian Institute of Marine Science, 2003): 2.

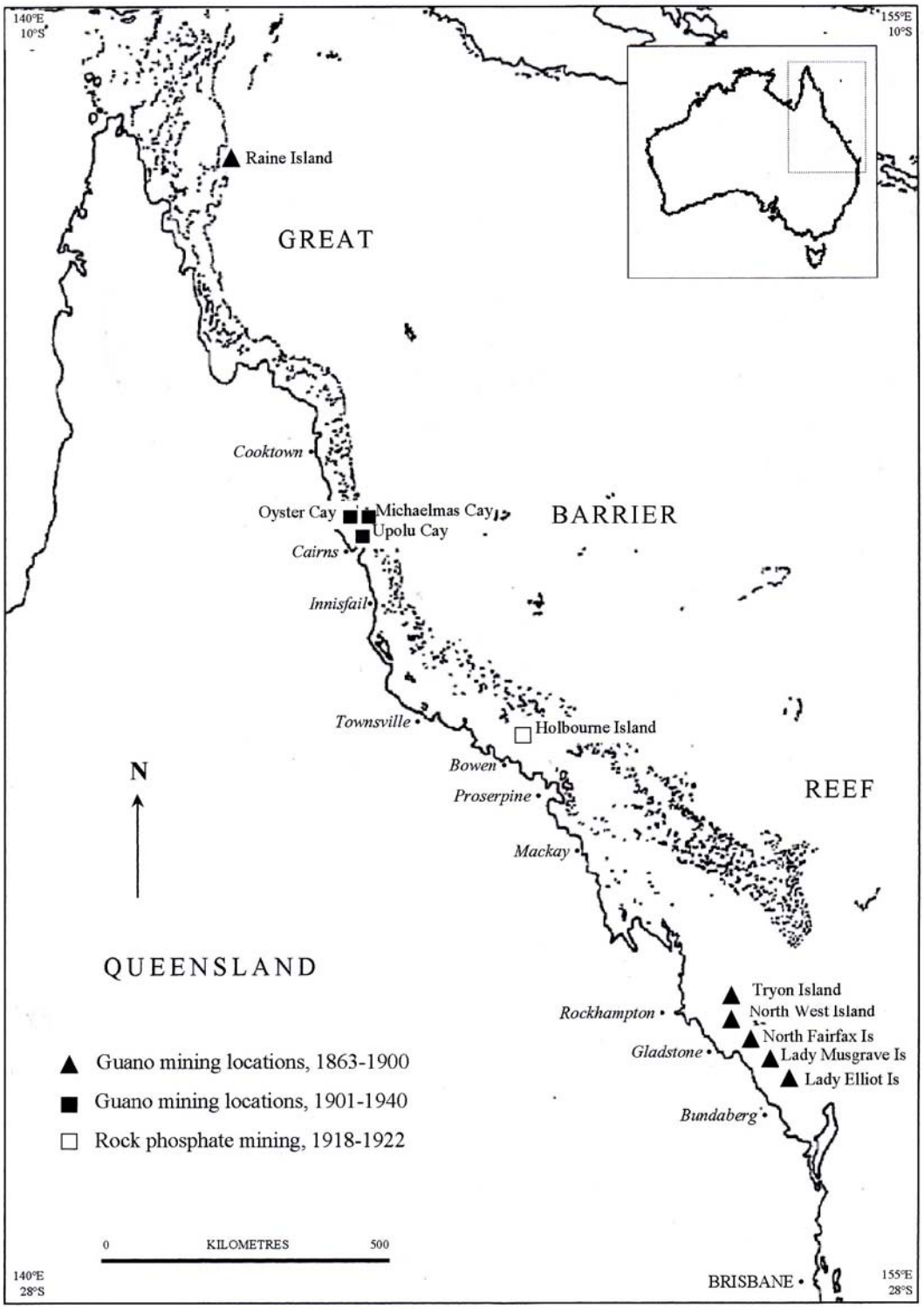

FIGURE 2. Guano and rock phosphate mining locations in the Great Barrier Reef.

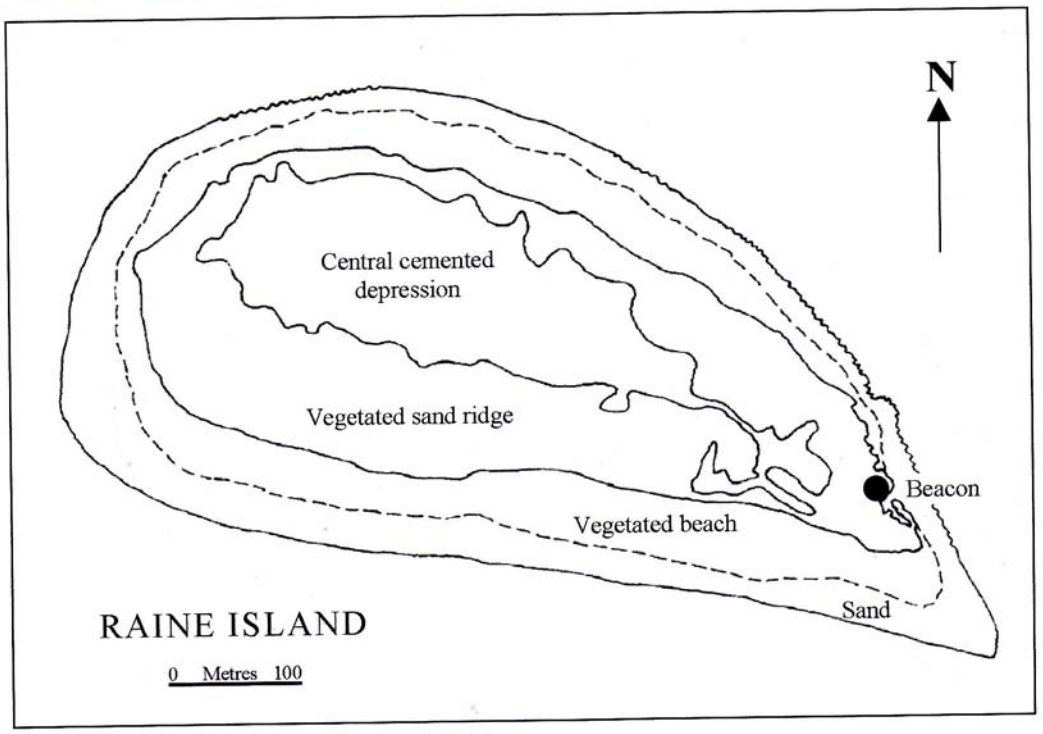

FIGURE 3. Map of Raine Island, showing the central depression exposed as a result of guano mining.

Source: Adapted from map obtained from the Queensland Environmental Protection Agency (QEPA), courtesy of Dr C. J. Limpus; see also C. J. Limpus, J. D. Miller, C. J. Parmenter and D. J. Limpus, 'The Green Turtle, Chelonia mydas, Population of Raine Island and the Northern Great Barrier Reef: 1843–2001', *Memoirs of the Queensland Museum* 49 (2003): 349–440, 357.

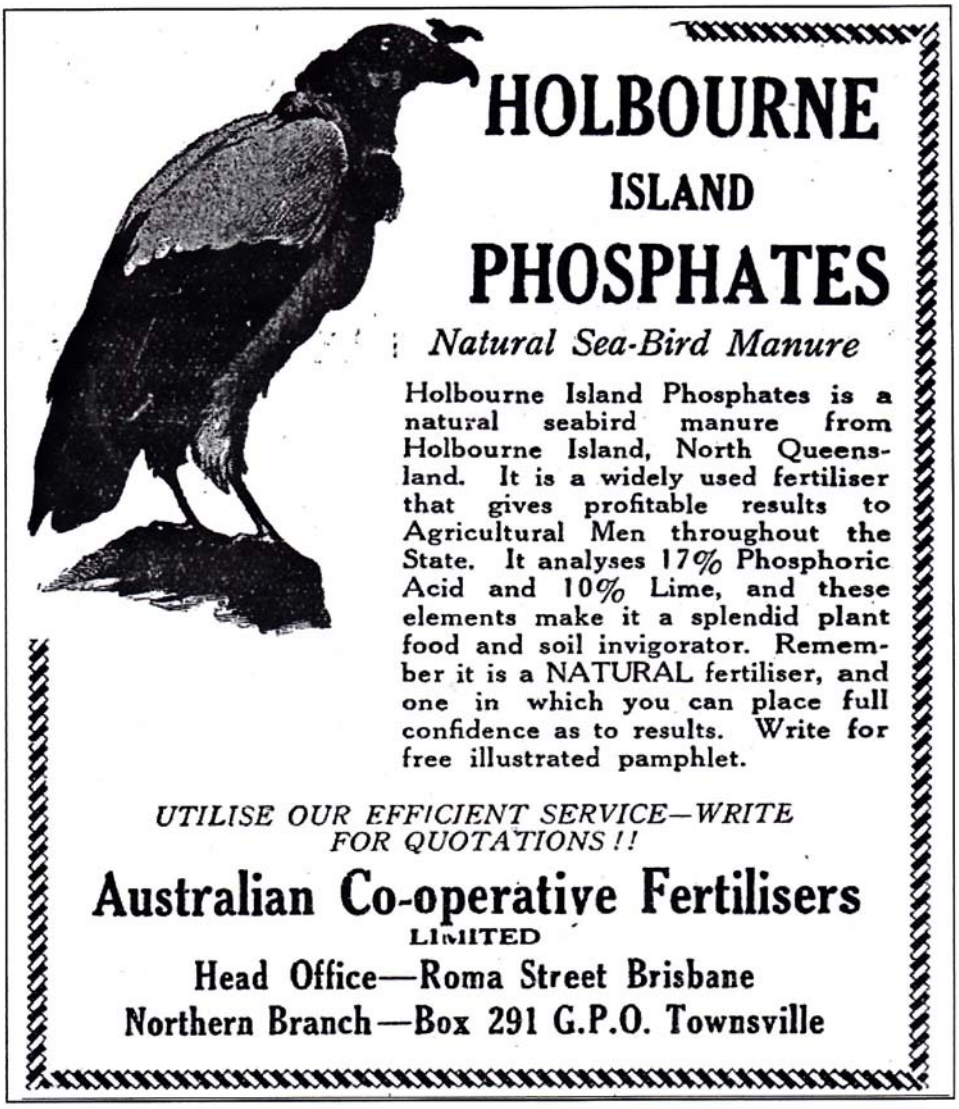

FIGURE 4. An advertisement for Holbourne Island phosphates, 1921.

Source: *The Australian Sugar Journal*, 5 August 1921, 273.

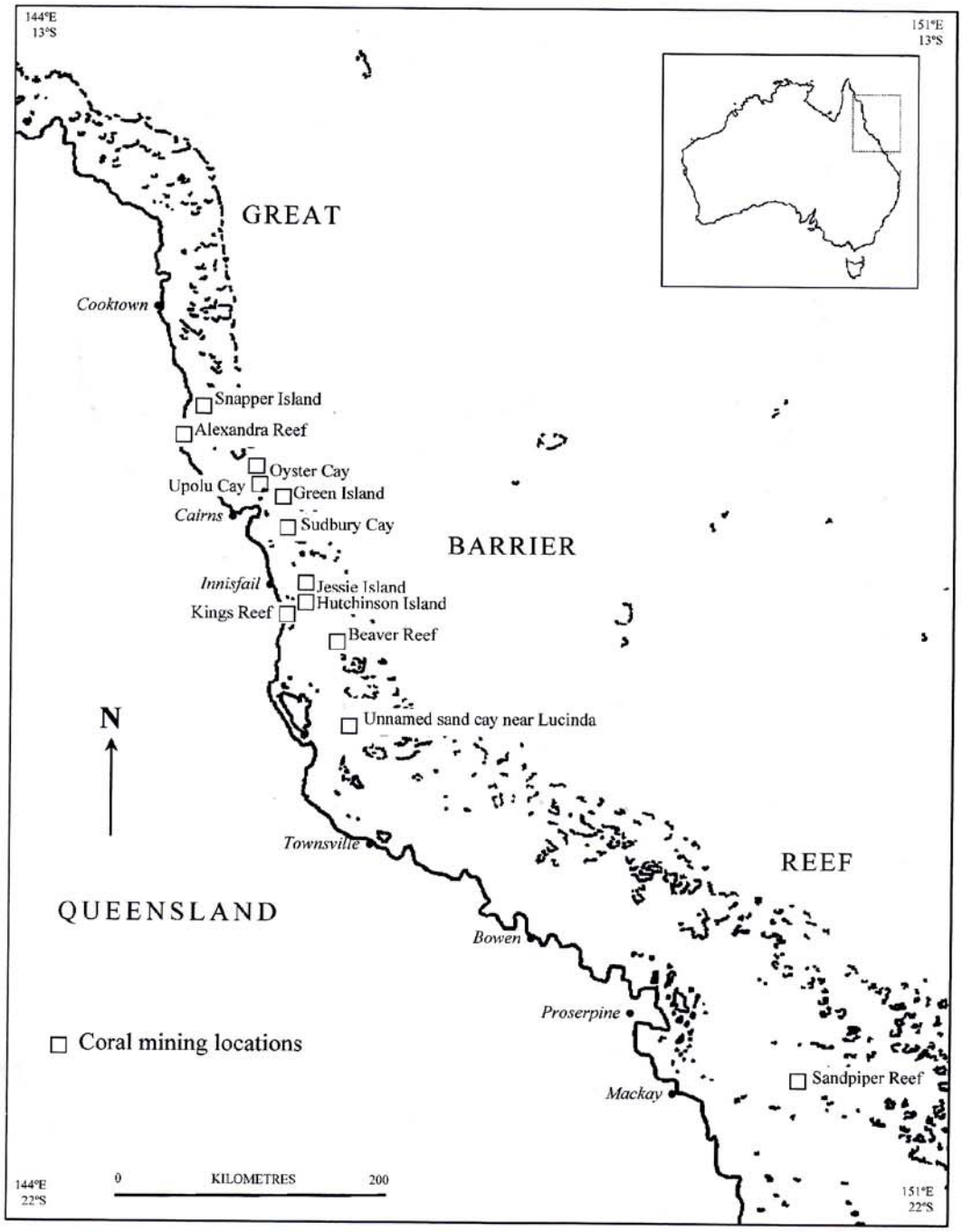

FIGURE 5. Coral mining locations in the Great Barrier Reef, 1900-1940.

Sources: Compiled from archival files contained in PRV8340/1 Item 1, QSA, and also from details provided in Oral History Cassette (OHC) 16, 2 September 2003; OHC 17, 2 September 2003; and OHC 28, 19 September 2003, *passim.*

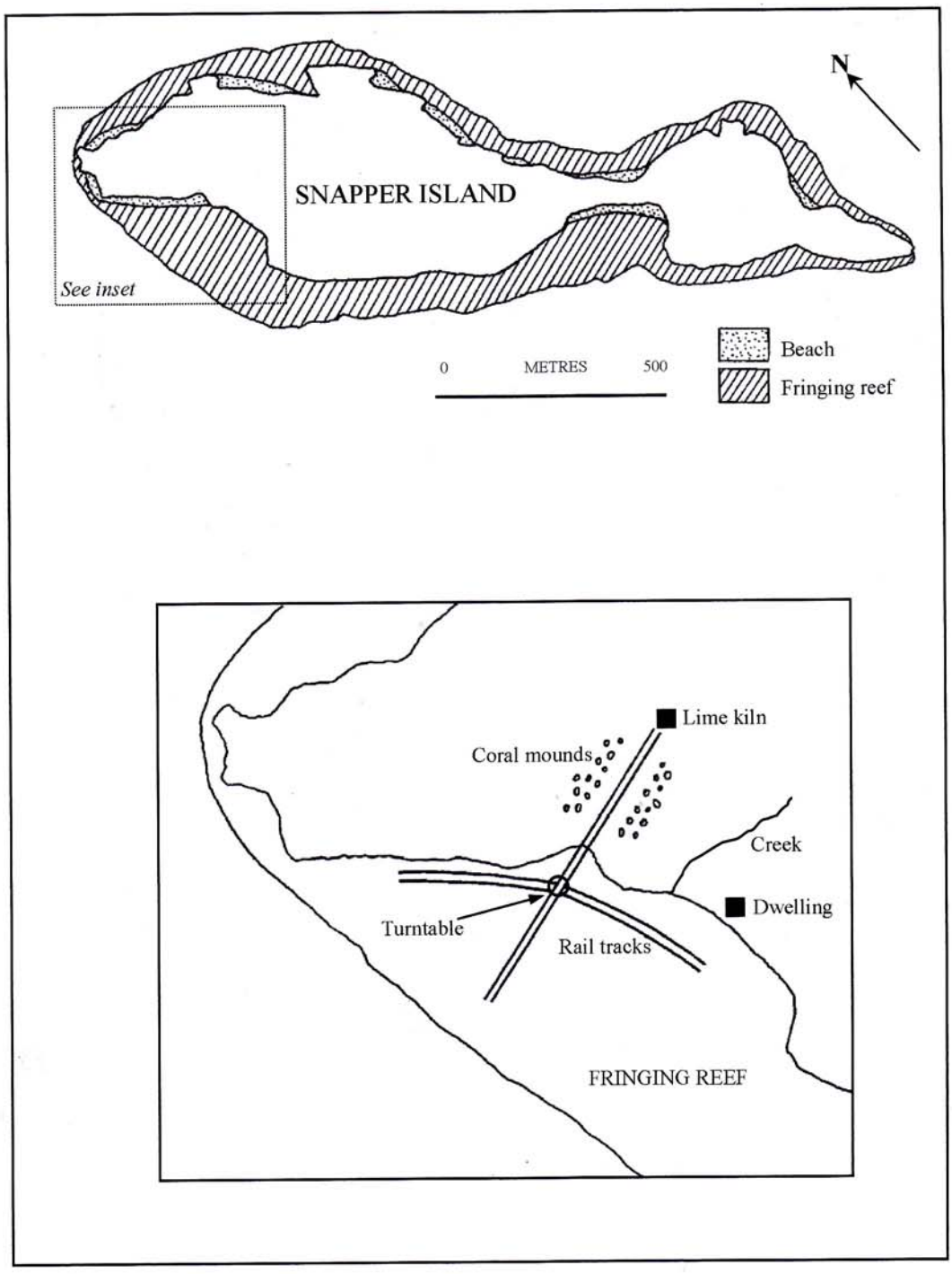

FIGURE 6. The location of the coral mining operation at Snapper Island.

Sources: Compiled from information in OHC 17, 2 September 2003, 3 and Queensland Environmental Protection Agency (QEPA), *Visitor Information: Snapper Island National Park and Marine Park* (Brisbane, QEPA, 2003).

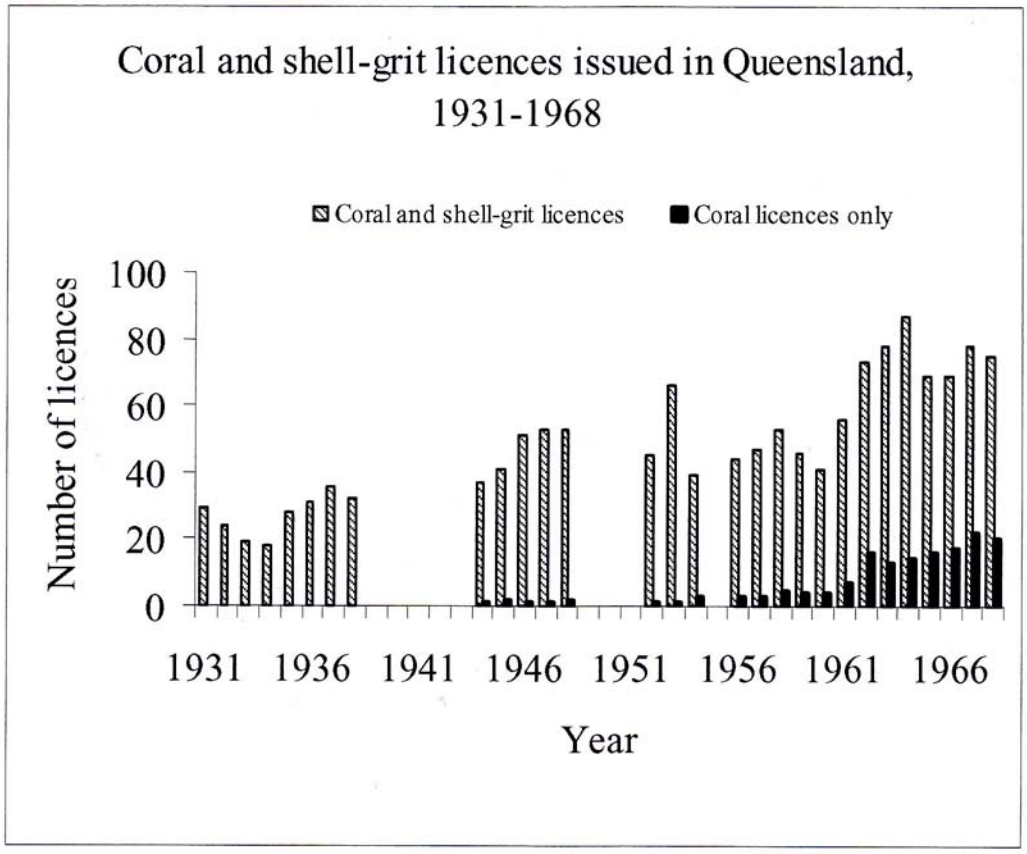

FIGURE 7. Numbers of coral and shell-grit licences issued in Queensland between 1931 and 1968. After the Second World War, a distinction was made between coral and shell-grit licences; Figure 7 indicates both the total number of coral and shell-grit licences issued and the number of licences issued specifically for the removal of coral.

Sources: Compiled from data provided in the Annual Reports of the QDHM, *QPP* (1932-1969), *passim*.

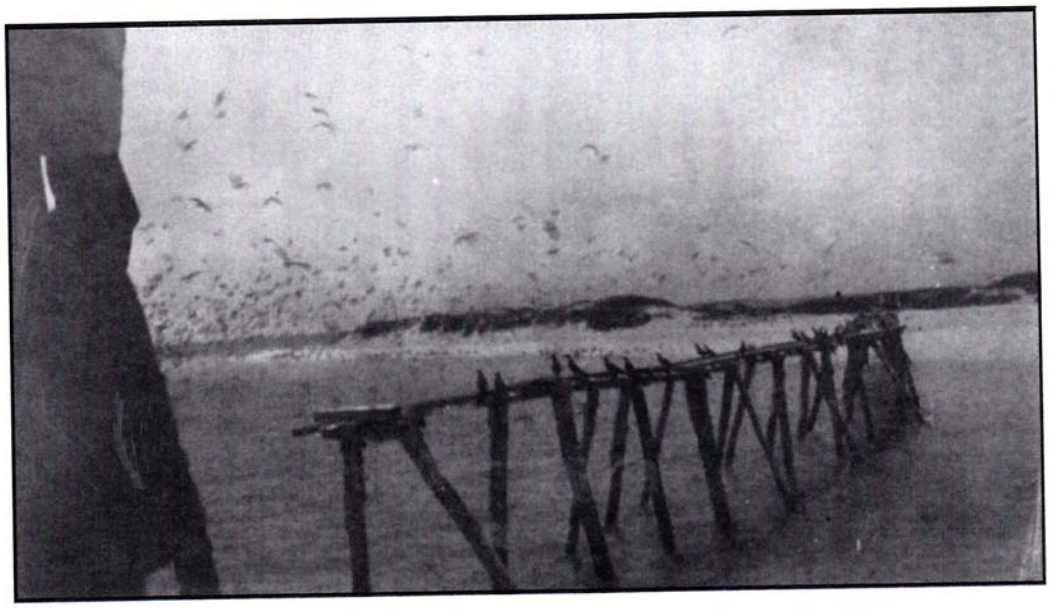

FIGURE 8. The jetty and tramline at Upolu Cay used for loading material mined from the cay, *c*.1933.

Source: PRV8340/1 Item 1, QSA.

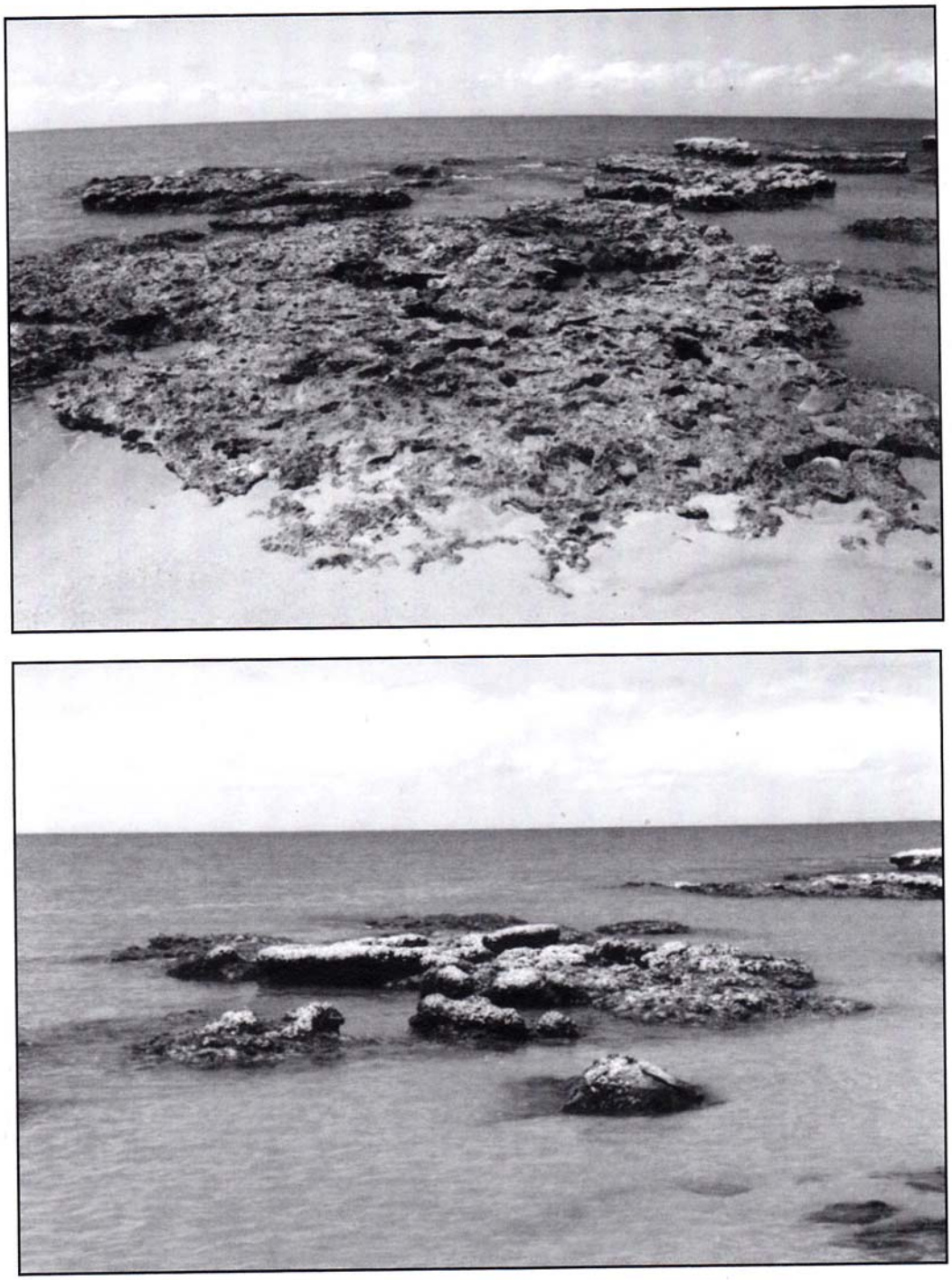

FIGURE 9. Alexandra Reef, near Port Douglas, 2003.

Source: Photographs taken by Ben Daley.