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Mining the Reefs and Cays: Coral, Guano and Rock Phosphate Extraction in the Great Barrier Reef, Australia, 1844–1940

BEN DALEY

*Department of Environmental and Geographical Sciences
Manchester Metropolitan University
John Dalton Building
Chester Street, Manchester M1 5GD, UK
Email: b.daley@mmu.ac.uk*

PETER GRIGGS

*School of Tropical Environment Studies and Geography
James Cook University – Cairns Campus
PO Box 6811
Cairns
Queensland, Australia 4870
Email: peter.griggs@jcu.edu.au*

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 occurred 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 suggest 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. Many authors have claimed that global marine environments are experiencing a critical deterioration as a result of over-harvesting, pollution and climate change. 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, including a significant reduction in coral cover during the last 40 years. Concerns about the 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. 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. Commercial and recreational fishing, tourism and coastal development represent other impacts on the ecosystem, as Lawrence *et al.* 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.¹

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. However, few other environmental histories of the Great Barrier Reef have been written, and the studies by J. and M. Bowen provide limited information about specific changes in particular coral reefs. Hughes *et al.* 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'. For many coral reef ecosystems world-wide, including the Great Barrier Reef, Hughes *et al.* and Pandolfi *et al.* have attempted to delineate the extent of the ecological changes resulting from human exploitation of coral reefs, including the sharp declines of many populations – especially large carnivores and herbivores – prior to the twentieth century. Hughes *et al.* argued

that the resilience of coral reef ecosystems to acute disturbance events has been eroded by chronic human impacts, including over-fishing of herbivores and the eutrophication and pollution of coastal waters. As a result of such impacts, Pandolfi *et al.* claimed, coral reef ecosystems are unlikely to survive without immediate protection from human exploitation over large geographical areas.²

Yet while these authoritative reconstructions indicate the systematic decline of coral reefs, many environmental historians have acknowledged the difficulties involved in constructing ecological baselines for complex ecosystems that are characterised by constant change. Furthermore, systematic scientific monitoring of the Great Barrier Reef extends back only to around 1970 and scarce scientific information exists for the earlier period. In addition, while Hughes *et al.* and Pandolfi *et al.* have reconstructed the vast scale of the ecological transformations of coral reefs, less attention has been paid to geomorphological changes, even though changes to the physical structure of coral reefs frequently involve habitat fragmentation and habitat loss – factors that have been implicated in degrading and reducing the resilience of ecosystems, as Hughes *et al.* acknowledged. Overall, anecdotal reports of the deterioration of the ecosystem – including damage to the structure of coral reefs – 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 to refute such reports.³

In the absence of sufficient scientific data, qualitative sources have been used to 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 used many official records of the Queensland Department of Agriculture and Stock (QDAS), Queensland Department of Harbours and Marine (QDHM), Queensland Environmental Protection Agency (QEPA), Cairns City Council and Queensland Premier's Department held in the Queensland State Archives (QSA) in Brisbane. Those records were supplemented with evidence gained from analysis of official reports of the Queensland Bureau of Sugar Experimental Stations (QBSSES), published in the *Queensland Parliamentary Papers (QPP)*, from export statistics published in the *Statistics of the Colony of Queensland (SCQ)* and in the *Statistics of the State of Queensland (SSQ)*, 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.⁴

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. In addition, no overview of the rock phosphate mining operation at Holbourne Island from 1918 to 1921 has previously been written. Furthermore, while Endeavour claimed that no limestone mining had occurred in the Great Barrier Reef, and Carruthers' 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 the contemporary management of the GBRWHA.⁵

The ecological significance of these activities is indicated by a variety of studies of mining impacts on other coral reefs. Guano and rock phosphate mining have resulted in the clearance of island vegetation; the introduction of exotic species, including chickens and goats, by miners; deliberate and accidental fires; and increased erosion of islands and cays, with the consequent transport of sediments to reefs. Coral mining has also been responsible for dramatic reductions in the size of cays and coral reefs; increased erosion of the remaining structures, leading in some cases to the complete disappearance of cays; significant reductions in coral cover and coral diversity, especially *Acropora* species; increased turbidity and sedimentation; enhanced colonisation of coral reefs by algal species; decreases in fish abundance; mangrove deforestation in order to supply fuel for lime burning; and increased vulnerability to other impacts, including tropical cyclones. Within the broader context of deteriorating water quality and increasing sea surface temperatures, these impacts can cause coral reef ecosystems to cross thresholds of mortality from which recovery may be extremely unlikely.⁶

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

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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, together with its terrestrial catchment, is shown in Figure 1. The ecosystem extends for over 2,000 kilometres along the north-eastern coast of Queensland, containing more than 2,900 coral reefs and representing one of the most biologically diverse ecosystems known to exist. The Great Barrier Reef is a young structure in geological terms, having formed during the last 10,000 years (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 as a separate British colony in December 1859) and its natural resources were subjected to more intensive exploitation, especially after 1900.⁷

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 (for example, Port Curtis (later Gladstone), Rockhampton, Port Denison (later Bowen) and 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 (*Toona ciliata*) from the tropical rainforests that were found on the Queensland coast between Cooktown and Cardwell. Gold mining was established at several locations (for example, Cooktown, Charters Towers, Ravenswood and 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 southern Queensland, wheat and maize became the dominant crops, while other settlers pursued dairying.⁸

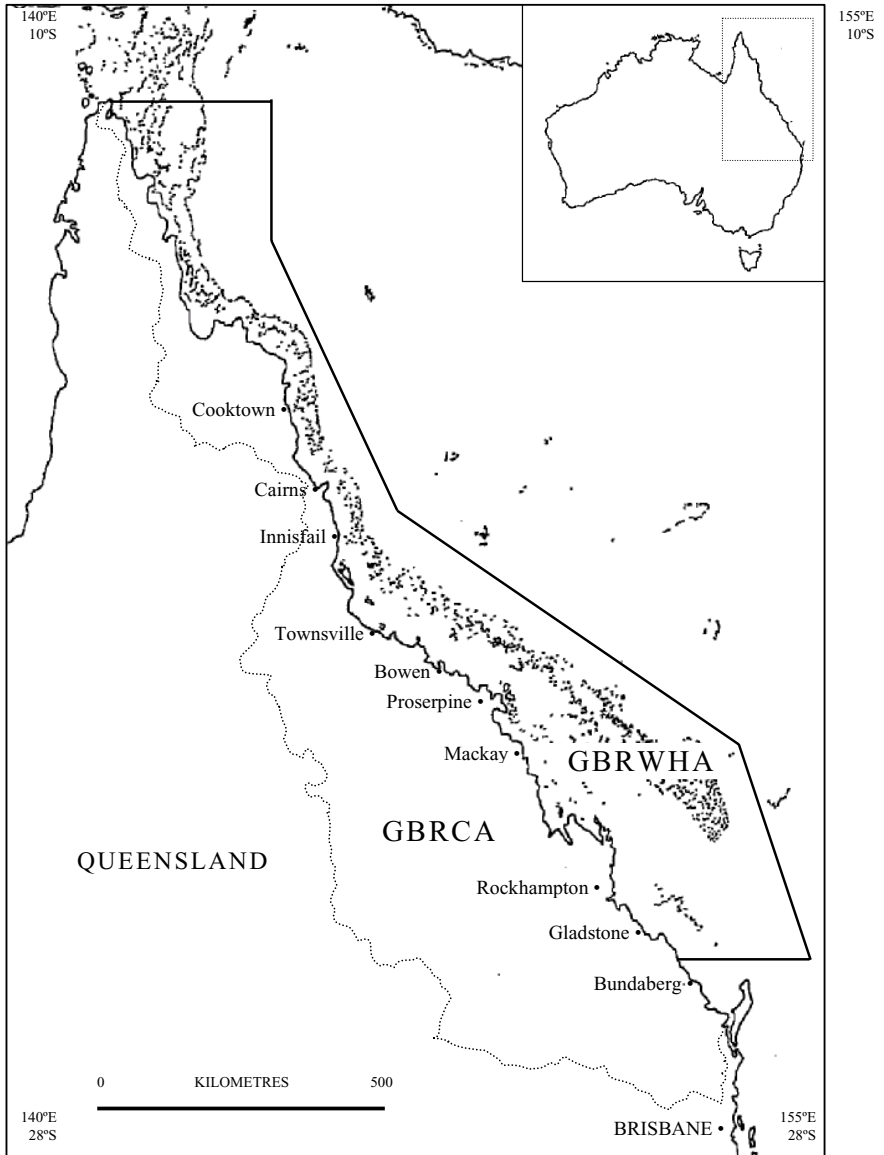


FIGURE 1. The geographical extent of the Great Barrier Reef World Heritage Area (GBRWHA) and the Great Barrier Reef Catchment Area (GBRCA).

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

Direct 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 *bêche-de-mer* (or trepang) and pearl-shell from the reefs, while dugongs and turtles were harvested from scattered inshore localities (for example, Heron Island, Cardwell and 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 (for instance, Green Island). 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.⁹

The spread of European settlement in Queensland was accompanied by a range of ecological impacts, as several authors have acknowledged. Furnas documented the extent of soil erosion in the Great Barrier Reef catchment resulting from land clearance and vegetation change, especially for the period since 1900, and the consequent several-fold increase in sediment and nutrient run-off to the Great Barrier Reef. Furnas also provided evidence of the detrimental impact of this sediment on corals, stating that many coral reef ecosystems are 'unlikely to recover to a healthy state under present conditions'. Particular ecological impacts resulted from the expansion of sugar cane acreage, the intensification of production on existing sugar cane land and the increasing adoption of scientific methods in sugar cane farming. The expansion of sugar cane land between 1865 and 1900 resulted in the complete deforestation of land in order to create farmland, and the cutting of timber to supply sugar mills with a source of fuel, with the result that further sediment run-off to the Great Barrier Reef occurred.¹⁰

The adoption of new agricultural practices by Queensland sugar cane farmers was one factor that contributed to the increase in terrestrial run-off to the Great Barrier Reef. By 1910, sugar cane farmers had started to apply nitrogenous fertiliser to soils in the Great Barrier Reef catchment, following the outcome of soil analyses conducted by the Queensland Bureau of Sugar Experimental Stations (QBSES). Application rates of nitrogenous fertiliser by Queensland sugar cane farmers increased after around 1910, with a very substantial increase after 1950, and over-application of nitrogen occurred in some cane-producing districts; as a consequence, nutrient run-off to the Great Barrier Reef increased. A smaller increase in phosphorus application in Queensland occurred after around 1920. Phosphorus represents another essential nutrient for sugar cane growth; and, without the use of artificial fertilisers, soil phosphorus levels are generally low in uncultivated or new sugar cane areas, as Wood *et al.* acknowledged.¹¹

The soil analyses carried out by the QBSES also indicated that the acidic soils of the northern coastal districts – including the Mossman, Cairns, Innisfail and Tully districts – required agricultural lime. However, prior to 1945, the Mossman, Cairns, Innisfail, Ingham and Mackay districts had limited terrestrial sources of lime other than the inland sources at Chillagoe and Ambrose, near Mount Larcom. In 1915, the QBSES reported that efforts were being made to produce agricultural lime by pulverising coral from the Great Barrier Reef. Agricultural lime manufactured from coral had the advantages of being comparatively cheap and chemically pure. The following year, the QBSES found that interest in coral sand and coral lime was high amongst sugar cane farmers and that pulverising machines were already available on the market; farmers were advised by the QBSES to use coral lime, chemical fertilisers and green manures. By 1920, lime derived from coral reefs was already being applied in the Mossman, Goondi, Mourilyan and South Johnstone areas. Overall, the outcome of the adoption by Queensland sugar cane farmers of more input-intensive agriculture was the creation of demand for fertilisers obtained from guano, rock phosphate and coral lime.¹²

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. 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; the naturalist Joseph Beete Jukes wrote that the latter were 'to be got in abundance from the reef at low water'. The completed beacon comprised a circular tower, 40 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 70 feet. 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. In addition, the removal of *Tridacna* and *Hippopus* clams 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.¹³

GUANO MINING, 1863–1940

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

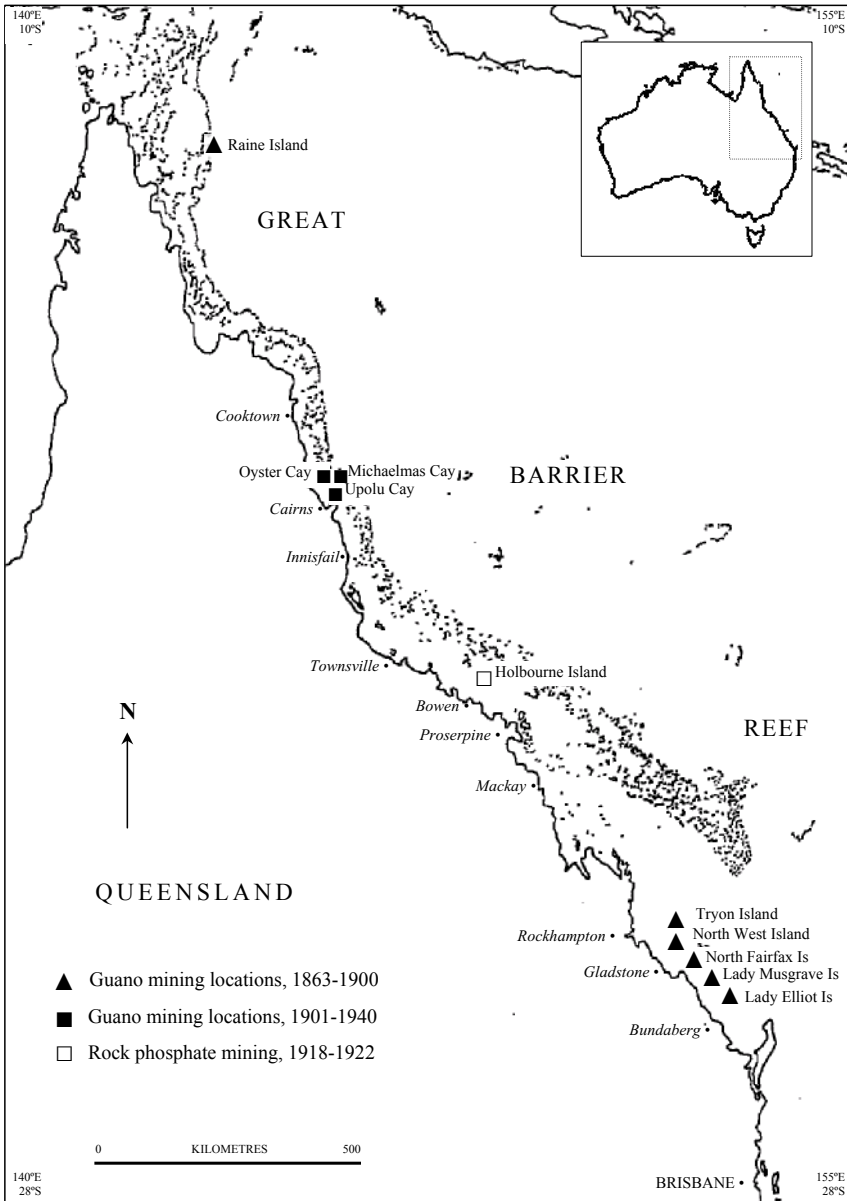


FIGURE 2. Guano and rock phosphate mining locations in the Great Barrier Reef.

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. 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 their commercial resources; other cays, such as Upolu and Michaelmas, were exploited less intensively, but over much longer periods.¹⁴

The date of the earliest guano mining in the Great Barrier Reef is disputed; one account, by Golding, stated that the industry was pioneered by William L. Crowther, of Hobart, who applied to the New South Wales Government in 1861 for licences to mine guano from Wreck Reef and Cato's Bank. Golding claimed that, before the permits were issued, Crowther had commenced removing guano from Wreck Reef; 100 tons of guano had been loaded onto the *Harp* when that boat was wrecked 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.¹⁵

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. After extraction from the island, the guano was dried, broken down and collected into sheds before being loaded onto barges. A system of tramways, sheds and moorings for the guano 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 wrote that little of the original vegetation remained. Heatwole, 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 concluded, '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'.¹⁶

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 had commented on the enormous number 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, that lease was renewed. 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 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.¹⁷

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 labour force – of approximately 100 Chinese and Malay workers – and ten European supervisors. The huts, tramway, locomotive and jetty were installed at this time in order to transport

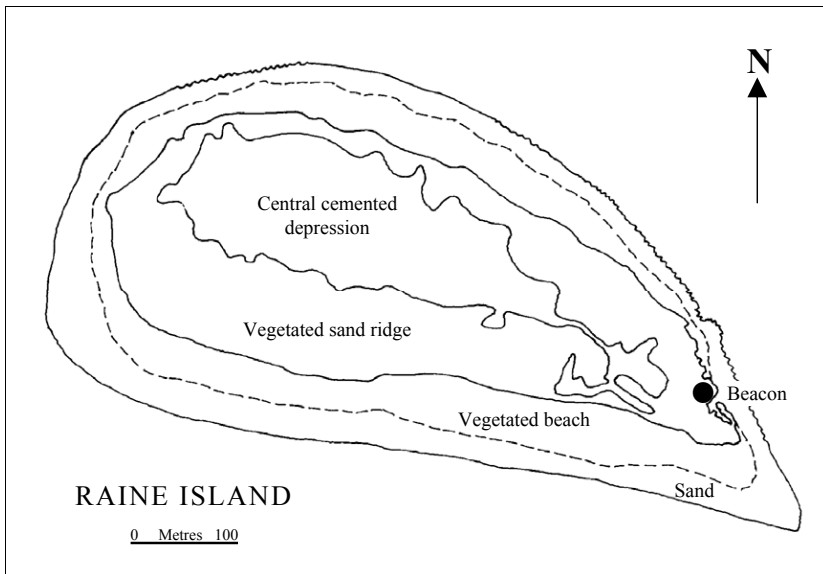


FIGURE 3. Map of Raine Island, showing the central depression exposed as a result of guano mining.

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.

'tens of thousands of tons of phosphate' from the island to the ships. By 1892, however, the mining ceased and the huts, tramway and jetty were removed from the island. A depression, exposed 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 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.¹⁸

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. 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'. 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*.¹⁹

One account of guano mining at North Fairfax, North West and Lady Musgrave Islands was provided by Ellis, in 1936, who 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.²⁰

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. Golding 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. As a result, Heatwole described North

West Island as 'the most disturbed of the uninhabited islands' in the Capricorn-Bunker Group.²¹

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 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.²²

However, guano mining continued after this date at Michaelmas, Oyster and Upolu Cays, near Cairns, in a less intensive manner, but for longer periods. 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. 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. The operation raised public concerns about the destruction of the cays. One individual wrote to the Queensland Minister for Mines, asking if the Minister could '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'. Nevertheless, the mineral leases for these cays were renewed in 1922 and the removal of guano continued.²³


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 1863 until around 1940 (see Figure 2). 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. In 1928, Bedford 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 1936 during a geographical expedition, and at North West Island, in the same year, Steers reported 'noticeable erosion' of the cay, which had been exacerbated, he suggested, by the removal of guano. Hopley argued that,

at islands where the geomorphological impacts of guano mining were 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.²⁴

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. 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 re-issued as Mineral Leases Nos 66 and 67, which were in turn replaced by Mineral Lease No. 73. 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.²⁵

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. 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 Co. Ltd, in May 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. 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. After 1921, no further working of phosphate



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

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

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.²⁶

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. Lime was used to make mortar, but burnt coral was also used as a building material in its own right. In 1864, G. Bowen informed the Royal Geographical Society of London that the creation of a new settlement at Port Albany, Cape York was facilitated by the presence there of 'large beds of coral, of the best description for making lime'. In 1872, Eden reported collecting 'coral to burn for lime' from reefs near Cardwell, and in an early description of Queensland, A. J. Boyd 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. 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.²⁷

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. Investigations by agricultural scientists from the QBSES in the early 1900s had revealed 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. Burnt lime was also used as a settling agent in the process of manufacturing raw sugar. In 1915, the QBSES reported that, in North Queensland, terrestrial sources of lime were expensive. Ernest Scriven, 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'.²⁸ The following year, Scriven 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.²⁹

MINING THE REEFS AND CAYS

Thus, coral mining for agricultural lime commenced in 1900 and continued until at least 1940. During this period, at least 12 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. This informant 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.³⁰

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. The lime kiln was fired using timber 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. 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.³¹

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 reported 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.³²

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). 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 recreational fisher, who recollected the mining operation stated, 'I

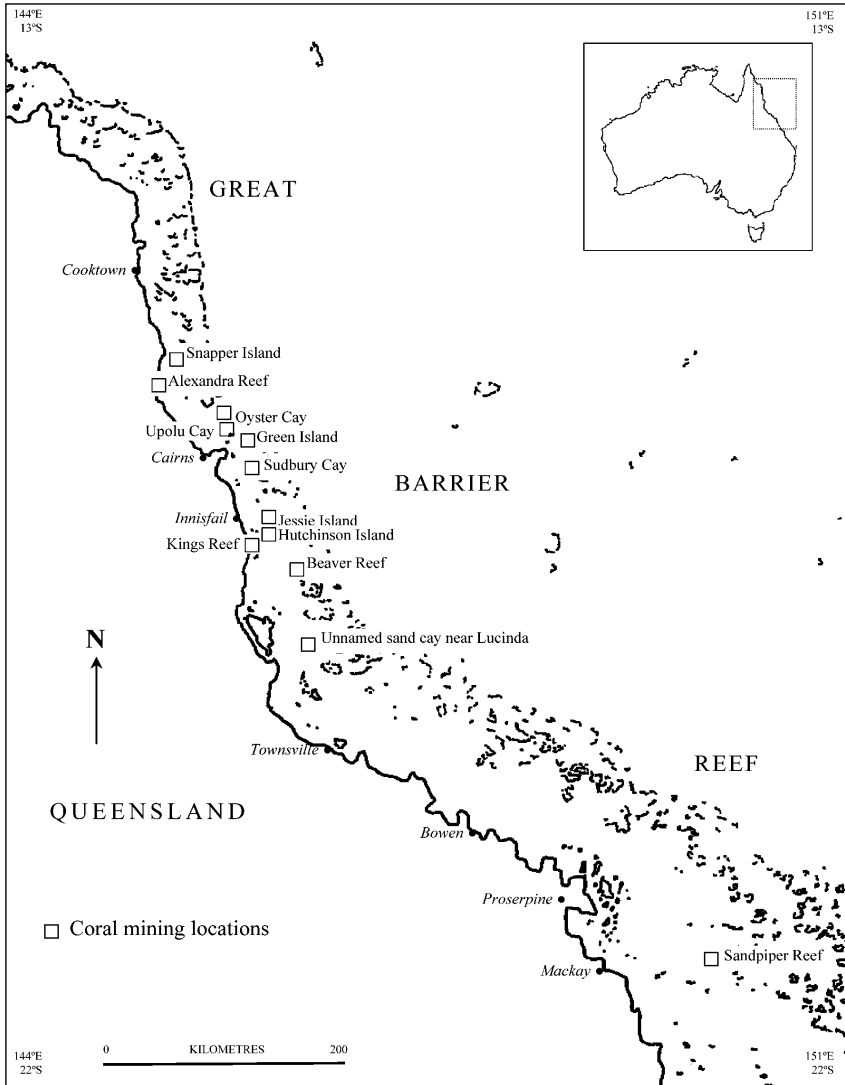


FIGURE 5. Coral mining locations in the Great Barrier Reef, 1900-1940.

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*.

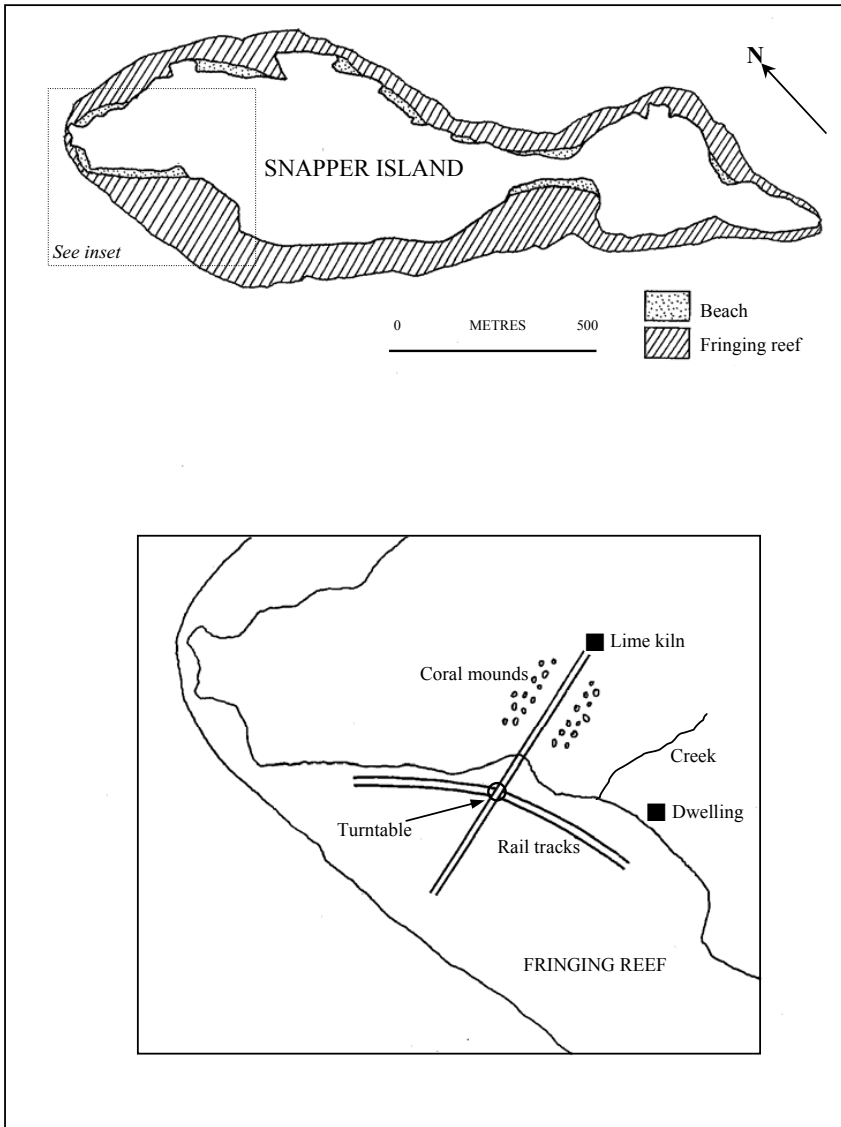


FIGURE 6. The location of the coral mining operation at Snapper Island.
 Sources: Compiled from information in OHC 17, 2 September 2003, 3 and Queensland Environmental Protection Agency (QEPA), *Visitor Information: Snapper Island National Park and Marine Park* (Brisbane, QEPA, 2003).

can remember the railway lines across the reef at Snapper Island, on the south-west corner, where the spring is'. This informant also 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 is 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.³³

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.

Another oral history account, by a retired cane-cutter, indicates that coral mining was carried out at Snapper Island by Jim Tyrie. 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 has since grown up again. [...] They had a portable tramline, like this tramline here [*indicates a nearby cane track*] [...]. The portable rail is only 20 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. The coral was about two foot [...]: some would be a metre long. 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.³⁴

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

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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. 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.³⁵

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'. However, some evidence of the scale of the operation remains in the landscape, as the 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 would spin it round and take it this way [*indicates map*] and tip it into the hole. You could see all that.³⁶

After Tyrie concluded mining at Snapper Island, one 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'. The evidence presented above suggests that, by that time, a considerable amount of coral had been removed from Snapper Island reef.³⁷

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. 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.³⁸

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 16 tons per day but the estimated daily output is six tons per day.³⁹

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.⁴⁰

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 20 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.⁴¹

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. 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, 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.⁴²

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. Companies as well as individuals made applications to mine coral. In 1929, Great Barrier Reef Fisheries Ltd 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. No evidence was found in the QSA to indicate whether or not these leases were granted.⁴³

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 of Cooktown applied for leases to dredge coral sand from twelve locations, comprising more than 50 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. 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.⁴⁴

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. 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 and Maurice Joseph Kenny of Yungaburra in 1930, whose company – Tanner and Kenny Contractors – applied to dredge for coral lime to produce fertiliser. 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.⁴⁵

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. One supporter of the industry, A. 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 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'.⁴⁶ 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 City Council (CCC) expressed its concern that the removal of coral from Green Island was threatening the popularity of the island with tourists. In correspondence with the Queensland Government, the CCC 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'. 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 CCC. That licence conferred sole rights to removal of coral from Green Island reef on the CCC. 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.⁴⁷

Nevertheless, the removal of coral continued in other locations in the Great Barrier Reef. From 1936–1938, extensive coral mining took place in the In-

nisfail 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). 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.⁴⁸

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. 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. This application indicates the willingness of investors to form syndicates to obtain coral leases and suggests that, by the end of the 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.⁴⁹

No archival evidence was found to indicate whether or not 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. 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 28 coral reefs in the Great Barrier Reef was prohibited. 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 Canegrowers' Executive – 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.⁵⁰

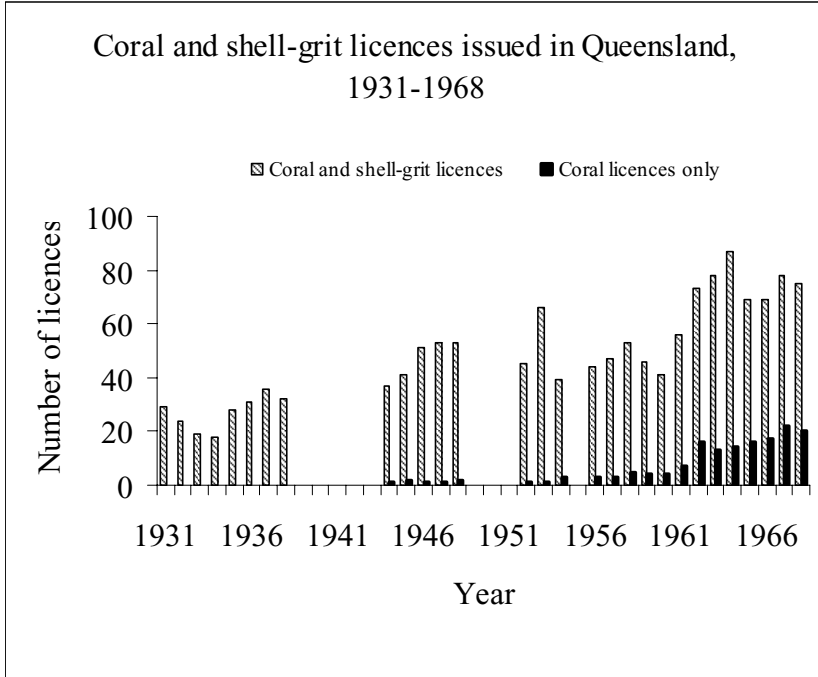


FIGURE 7. Numbers of coral and shell-grit licences issued in Queensland between 1931 and 1968. After the Second World War, a distinction was made between coral and shell-grit licences; Figure 7 indicates both the total number of coral and shell-grit licences issued and the number of licences issued specifically for the removal of coral. Sources: Compiled from data provided in the Annual Reports of the QDHM, *QPP* (1932-1969), *passim*.

The earliest indication of the ecological 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'. Material was removed from Upolu Cay by running a tramline into the centre of the cay and quarrying to a depth of about four feet (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. 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.⁵¹



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.

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. 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. 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.⁵²

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.⁵³

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.⁵⁴

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 and Alexandra Reefs are the reefs most likely to have been extensively degraded, since they were worked from a comparatively early date – before 1930 – and because, in comparison with the fringing reef at Snapper Island, they were more easily reached from the coast. In addition, while Snapper Island was inhabited sporadically, Kings and Alexandra reefs were accessible from population centres (including Kurrimine Beach, Innisfail, Port Douglas and Mossman) throughout the period since European settlement of the north Queensland 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. 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.⁵⁵

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. 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,



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

Source: Photographs taken by Ben Daley.

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.⁵⁶

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. In addition, as a result of the coral mining industry, between 1900 and 1940, at least 12 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 and Alexandra Reefs. 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 12 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.⁵⁷

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 reef ecosystems. 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 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 [...].⁵⁸

Additional evidence of the impacts of coral mining was provided by Soekarno, 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 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.⁵⁹

Hughes *et al.* 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.⁶⁰

Such comments may well apply to the 12 coral mining locations of the Great Barrier Reef. Furthermore, as Hughes *et al.* acknowledged, ecologists increasingly focus 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.⁶¹

CONCLUSION

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, Kings and Alexandra Reefs) being intensively mined and, most likely, dramatically modified. Since the 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. 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 of 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 of maintaining effective marine no-take areas (NTAs) in the GBRWHA, in which all extractive industry is prohibited. Hence, these findings support the call by Bellwood *et al.* for a range of 'more vigorous, innovative and adaptive management strategies' for the Great Barrier Reef.⁶²

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³⁵ OHC 17, 2 Sept. 2003, 2; this description of the operation is consistent with the account provided in OHC 16, 2 Sept. 2003, 4–5.

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⁵⁴ Jones, *Hurricane Lamps*, 317.

⁵⁵ See the discussion in OHC 35, 20 Oct. 2003, 6.

⁵⁶ OHC 16, 2 Sept. 2003, 4–6; OHC 17, 2 Sept. 2003, pp. 2–3 and 17; OHC 20, 9 Sept. 2003, 8.

⁵⁷ Hopley, *Geomorphology*, 376.

⁵⁸ Gomez, 'Perspectives on Coral Reef Research', 283 and 288–9.

⁵⁹ Soekarno, 'Comparative Studies on the Status of Indonesian Coral Reefs', 217.

⁶⁰ Hughes *et al.*, 'New Paradigms', 382.

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⁶² Bellwood *et al.*, 'Confronting the Coral Reef Crisis', 831; Hughes *et al.*, 'New Paradigms', 381.

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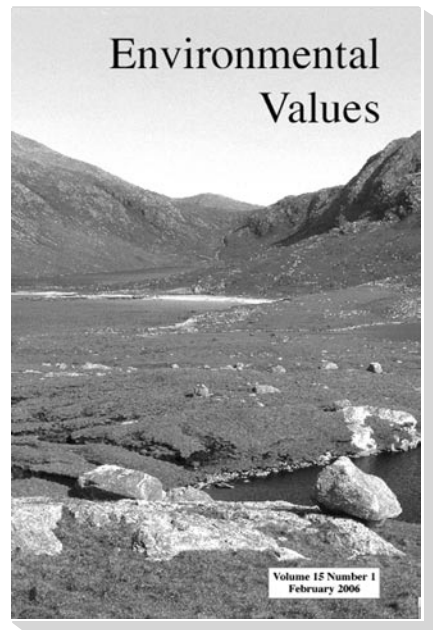
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