

**ATOLL RESEARCH BULLETIN  
NO. 254**

**NATURAL HISTORY OF RAINE ISLAND, GREAT  
BARRIER REEF**

**by D. R. Stoddart, P. E. Gibbs, and D. Hopley**

**Issued by  
THE SMITHSONIAN INSTITUTION  
Washington, D. C., U.S.A.  
July 1981**

## CONTENTS

Introduction	1
General description	5
Geology and geomorphology	6
Topography	6
Lithology	7
Stratigraphy	8
Sediments	8
Interpretation and subsequent observations	9
Phosphate deposits	10
Water supply	11
Vegetation and flora	11
Invertebrates	14
Marine Turtles	14
Birds	17
<i>Ducula spilorrhoa spilorrhoa</i>	17
<i>Rallus philippensis yorki</i>	17
<i>Gallinula porphyrio melanotus</i>	19
<i>Puffinus pacificus</i>	19
<i>Pterodroma arminjoniana heraldica</i>	20
<i>Fregata minor</i>	20
<i>Fregata ariel</i>	20
<i>Sula leucogaster plotus</i>	22
<i>Sula sula rubripes</i>	24
<i>Sula dactylatra personata</i>	25
<i>Pelecanus conspicillatus</i>	26
<i>Phaethon rubricauda</i>	27
<i>Sterna bergii</i>	27
<i>Sterna fuscata nubilosa</i>	28
<i>Sterna anaethetus anaethetus</i>	29
<i>Anous stolidus pileatus</i>	29
<i>Anous minutus minutus</i>	30
<i>Larus novaehollandiae forsteri</i>	30
<i>Arenaria interpres interpres</i>	30
<i>Pluvialis squatarola</i>	30
<i>Pluvialis dominica fulva</i>	31
<i>Numenius phaeopus variegatus</i>	31
<i>Limosa lapponica baueri</i>	31
<i>Calidris ruficollis</i>	31
<i>Calidris acuminata</i>	31
<i>Egretta alba modesta</i>	31
<i>Egretta sacra</i>	31

<i>Nycticorax caledonicus hilli</i>	32
<i>Merops ornatus</i>	32
<i>Hirundo nigricans nigricans</i>	32
<i>Myiagra rubecula rubecula</i>	32
<i>Aplonis metallica metallica</i>	32
Disturbance by Man	33
Construction of the Beacon	34
Wreck of the <i>Enchantress</i>	36
Beche-de-mer Fishery	37
Phosphate mining	37
Acknowledgements	38
References	39

List of Figures

1. The northern Great Barrier Reef, showing the location of Raine Island.
2. Raine Island and its reef.
3. Monthly distribution of rainfall at Willis Island, 1921-1971 (data from Taylor 1973).
4. Raine Island in 1844, from Jukes (1847), vol. I, p. 338.
5. Profile of Raine Island, from Jukes (1847), vol. I, p. 339.
6. Map of Raine Island. The areas in the central guano flat are the seabird survey areas detailed in Table 2.
7. Topographic profile of Raine Island.
8. Sediment samples from Raine Island.
9. Histogram of curved carapace length of turtles measured on the nest, night of 3 November 1973.
10. Section and elevation of the Raine Island Beacon, 1844, after Bateson (1972), p. 201.

List of Tables

1. Visitors to Raine Island.
2. *Sula leucogaster* and *Sula dactylatra* in sample areas of the central guano flat, midday, 3 November 1973.

List of Plates

(grouped at the end of the paper)

1. Raine Island in 1844, from Jukes (1847).
2. The central guano flat from the west end of the island, looking towards the Beacon. The ridge in the foreground is the site of the old guano railway.
3. Eastern end of the central guano flat, with Brown and Masked Gannets.
4. Mounds of rubble and stones in the central guano flat.
5. Massive beachrock on the northeast shore.
6. Grooved and furrowed beachrock on the northeast shore.
7. Beachrock now distant from the beach on the north shore.
8. Phosphatic beachrock unconformably overlying old eroded beachrock at the east end of the island.
9. Cliffs in phosphate rock at the southeast end of the island.
10. Irregular lower surface of the phosphate rock, forming caves, on the south side of the island. Note the nesting Tropicbird beneath the overhang.
11. Detail of the columnar structure of the phosphate rock.
12. Detached remnants of phosphate rock, south side of the island.
13. Western sand beach, showing early morning turtle tracks.
14. Turtle nests on the beach crest at the west end of the island.
15. Green Turtle on the northeast beachrock.
16. Turtle remains in *Lepturus* grassland of the high ridge.
17. Shearwater burrows in fine guano at the west end of the central guano flat.
18. Mound in the central guano flat with juvenile Lesser Frigate-birds.
- 19-21. Juvenile Lesser Frigate-birds.
22. Brown Gannets lining the beachrock at the east end of the island.
23. Brown Gannets on beachrock on the northeast shore.

24. Brown Gannets on the nest in the central guano area. Note the twigs outlining the nest.
25. Brown Gannets nesting in the *Lepturus* grassland of the high ridge. No twigs surround the nest in the vegetated areas.
- 26-27. Masked Gannets on the nest in the central guano area. The nest is simply a depression in the sand.
28. Hatchling Masked Gannet in the central guano area.
29. Hatchling Masked Gannet with regurgitated flying fish *Cypsilurus melanocercus* in a nest in the central guano area.
- 30-31. Red-footed Gannets on nests built on low *Abutilon* shrubs on the high ridge at the west end of the island.
32. Fledgling Red-footed Gannet on the nest at the west end of the island.
33. Juvenile Red-tailed Tropic-bird under the phosphate cliffs at the east end of the island.
34. The Beacon and grave at the east end of the island, seen from the south in November 1973.
35. The Beacon as erected in 1844, from *Nautical Magazine*, vol. 14 (1845), p. 267.
36. The Beacon in November 1973. The dark area on the lower wall is that repaired by H.M.A.S. *Gascoyne* in 1961.
37. Inscriptions inside the walls of the Beacon.
38. The grave of Annie Eliza Ellis.

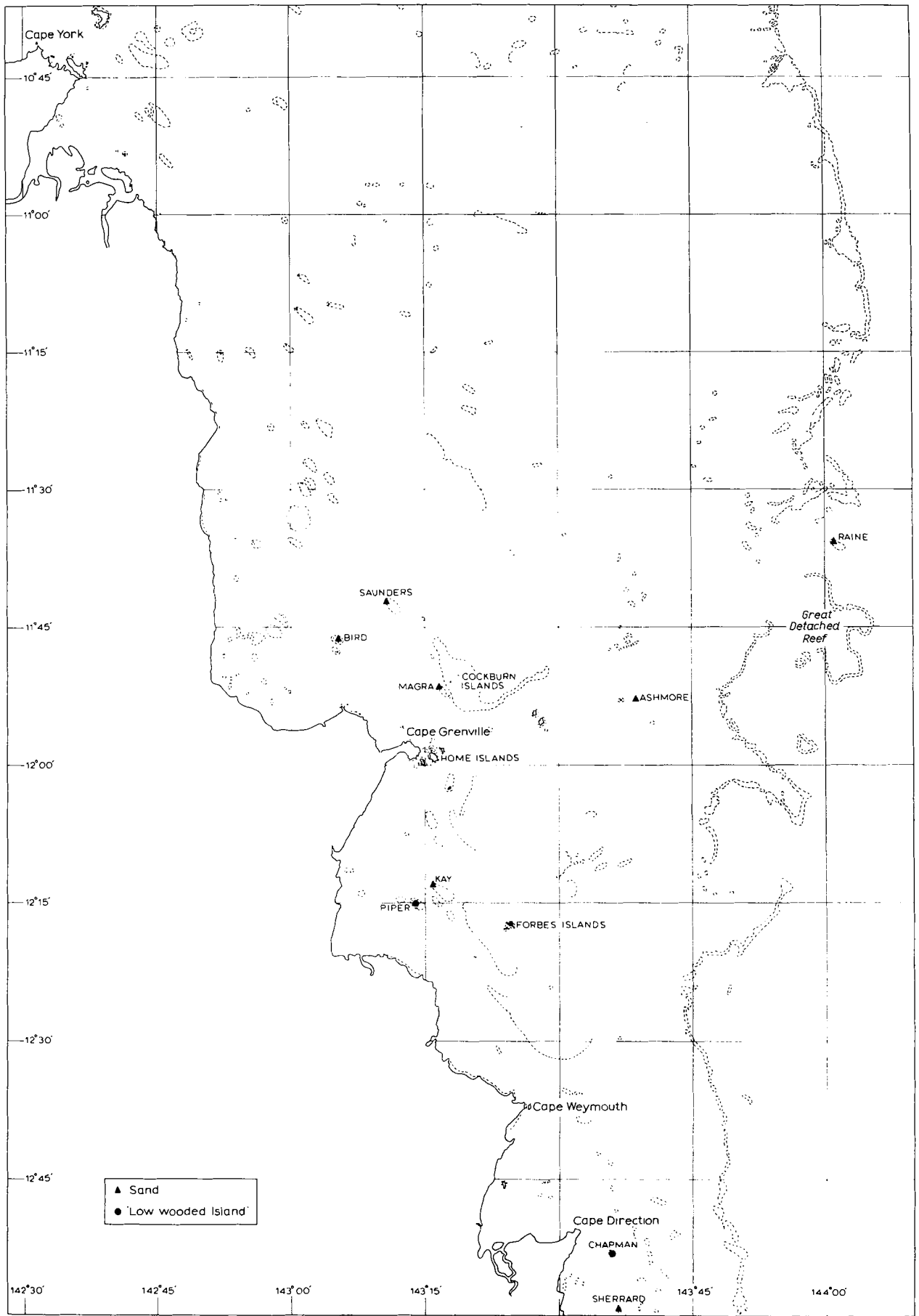


Fig. 1. The northern Great Barrier Reef, showing the location of Raine Island.

# NATURAL HISTORY OF RAINE ISLAND, GREAT BARRIER REEF

by D. R. Stoddart<sup>1</sup>, P. E. Gibbs<sup>2</sup>, and D. Hopley<sup>3</sup>

## INTRODUCTION

Raine Island, on the northern Great Barrier Reef, is a small sand cay 850 m long and up to 430 m wide. It was the subject of now classic descriptions by Joseph Beete Jukes and John MacGillivray during the voyage of H.M.S. *Fly* in 1843-45, when a substantial stone Beacon was built there. Several other scientific parties, including that of H.M.S. *Challenger*, have visited the island, but no general account exists of it. This is the more surprising, since it is the most important breeding station for tropical seabirds in Australia, and has recently been shown to be one of the world's largest nesting sites for the Green Turtle.

Much of Raine was originally covered with guano and lightly cemented phosphate rock, which formed the basis of a brief but considerable mining industry in 1890-92. Raine is, in fact, interesting not only in itself but also as a representative of a class of small, semi-arid guano and phosphate islands in the reef seas. Among those recently studied are several in the Amirantes in the western Indian Ocean; Laysan in the Leeward Hawaiian Islands; and several of the smaller Phoenix Islands in the central Pacific. Raine is the smallest of all of these: it is half the size of McKean and Birnie Islands in the Phoenix group, and half the size of the Marie-Louise in the Amirantes. Bird Island in the Seychelles is three times as big as Raine, and most of the other phosphate islands are much larger. But in spite of its small dimensions, Raine is of sufficient interest to merit bringing all the available information on it together, together with new observations from the work of the Royal Society and Universities of Queensland Expedition to the northern Great Barrier Reef in 1973.

- 
1. Department of Geography, Downing Place, Cambridge, England.
  2. Marine Biological Association of the U.K., The Laboratory, Citadel Hill, Plymouth, England.
  3. Department of Geography, James Cook University of North Queensland, Townsville, Australia.

Manuscript received August 1980 -- Eds.



Table 1. Visitors to Raine Island

2

Date	Vessel	Visitors	Notes	References
1815	<i>Surry</i>	Thomas Raine	First recorded sighting	
1843 29-30 July	H.M.S. <i>Fly</i>	Capt.F.P. Blackwood, J.B. Jukes	Short visit	
1844 29 May-mid September	H.M.S. <i>Fly</i>	Capt.F.P. Blackwood, J.B. Jukes, J. MacGillivray (June only), Lt J.M.R. Ince	Shore party camped to build beacon; vegetable gardens established. Geological, botanical and zoological work	Blackwood 1844a, 1844b, 1844c, Jukes, 1847, 1871; J. MacGillivray 1846
1845 25 January	<i>Heroine</i>	Capt.M. Mackenzie	Short visit; goats introduced	Mackenzie 1845
1845 April- May	H.M.S. <i>Bramble</i>	J. Sweatman	Short visit	Sweatman, MS
1846 5 August	<i>Heroine</i>		Short visit	Anon. 1846
1850 24-25 July	<i>Enchantress</i>	Capt. I'Anson	Wrecked	Lack 1953
1860(-)	H.M.S. <i>Salamander</i>	Capt. Mangles Denham, A. Rattray	Short visit	Rattray 1869
1862			Raine and other islands leased for guano digging	Crowther 1939
1865 March	H.M.S. <i>Herald</i>	Capt. Mangles Denham		

Table 1 continued

Date	Vessel	Visitors	Notes	References
1874 31 August	H.M.S. <i>Challenger</i>	Capt. G. Nares, with H.N. Moseley, J. Murray, J.Y. Buchanan	Short visit, botanical and zoological collections	Campbell 1876; Spry 1876; Swire 1938; Buchanan 1874; Forbes 1878; Sclater and Salvin 1878; Moseley 1879; Miers 1886; Murray 1895
1870's		Beche-de-mer fishery	Shore camps	Ellis 1936
1890-1892		Guano digging	Shore camps	Ellis 1936; Arundel, MS; Hutchinson 1950
1910 30 October		W.D.K. Macgillivray, E.H. Dobbyn	Ornithology	Macgillivray 1910; North 1912
1911 9-15 July		W.R. M'Lennan	Ornithology	Macgillivray 1914, 1917, 1918
1913 4-12 December		W.D.K. Macgillivray, W.R. M'Lennan	Ornithology	Macgillivray 1914, 1917, 1918
1957 July		D. Attenborough	B.B.C. film unit on Raine for 4 days	
1959 7-14 and 22 February		J. Warham	Ornithology; plants	Warham 1961, 1963, 1959
1961 11 November	H.M.A.S. <i>Gascoyne</i>	K.A. Hindwood, K. Keith, G.F. Mees, I. Thomas D. Woodland, A. Bartholomai	Ornithology; plants	Hindwood, Keith and Serventy 1963; Hindwood 1964

Table 1 continued

Date	Vessel	Visitors	Notes	References
1973 1-4 November	<i>James Kirby</i>	D.R. Stoddart, P.E. Gibbs, D. Hopley	Geomorphology, plant collection, ornithology, turtles, crabs	This report

Since 1973 there have been several visits to Raine Island by the staff of the National Parks and Wildlife Service of Queensland, the Department of Zoology of James Cook University, and the Australian Institute of Marine Science at Townsville.

## GENERAL DESCRIPTION

Raine Island is located at the leeward end of an oval patch reef 3.5 km long and 0.75 km wide, with an area of 210 ha, north of the Great Detached Reef of the northern Great Barrier Reef system, and 100 km ENE of Cape Grenville, the nearest point on the Queensland mainland (Figures 1 and 2). Its co-ordinates are 11°36'S and 144°01'E. Jukes (1847) described the island as 1000 yds (915 m) long, 500 ft (150 m) wide, and up to 20 ft (6 m) high above high water level. The central part of the island he described as covered with a cap of calcareous sandstone, terminating on its seaward sides in a cliff 4-5 ft (1.2-1.5 m) high. The Raine Island Reef has been termed a "small coral atoll" (Tizard *et al.* 1885, II, 530), but in the absence of a lagoon this usage seems inappropriate.

The first full descriptions of the island are those of Jukes (1847) and MacGillivray (1846), based on observations made during the time that a beacon was being built on the eastern end of the island by Capt F.P. Blackwood and H.M.S. *Fly* in 1844. The island was subsequently occupied during 1890-92, when tens of thousands of tons of phosphate were dug and exported. Twenty years later, at the time of W. Macgillivray's visits, seabirds were abundant, and the island is still "probably the most important breeding station for tropical seabirds in Australian seas" (Warham 1961, 77). It is also a major nesting site for Green Turtles, though this has attracted less attention in the scientific literature.

No weather records have ever been kept at Raine. During April to November the Southeast Trades blow constantly; during December to March the Trades retreat to the south and are replaced by calms and northerlies. Most rainfall occurs during this second period. Mean annual rainfall has been estimated by A.T. Bath (in Warham 1961) as 1000 mm (40 inches); this is very close to the mean for Willis Island in the Coral Sea (16°18'S, 149°59'E), where the mean annual rainfall 1921-1971 was 1098 mm (Figure 3). Reliability of rainfall at Willis, and probably also at Raine, is low; annual totals at Willis over the period of record range from a minimum of 240 mm (in 1966) to a maximum of 2024 mm (in 1959). Overnight dew is probably an important source of moisture on these islands.

Tidal range has been estimated as 10-12 ft (3.0-3.7 m) (Blackwood 1844a, 540; Fairbridge 1950, 352). Mean tidal range at springs for islands closer to the mainland between Cape Grenville and Cape Melville, however, ranges from 5.2 to 6.8 ft (1.6-2.1 m), increasing northwards to 8.4 ft (2.6 m) near Cape York.

## GEOLOGY AND GEOMORPHOLOGY

Topography

MacGillivray (1846, 1474) described the following main features of the island:

- (a) a steep beach, 20 yards (18 m) or more in width.
- (b) a "more or less continuous, low, wall-like border of coral rock, its faces much decomposed by the weather, and hollowed out in a singular manner. ... This rock, which ranges from a conglomerate to a coarse sandstone, is in general soft and crumbles readily. ... This bed of sandstone is not more than a few feet in thickness, and exhibits proof of its recent formation, by containing shells and fragments of coral, specifically identical with living inhabitants of the reef, and occasionally eggs of turtle, apparently as if, while *in situ* in the loose sand of what was then a mere sand-bank, some chemical agency had converted the whole to a bed of stone". According to MacGillivray the edge of the cliff reached a height of 24 ft (7.3 m) above sea level.
- (c) a lower central area with a surface cover of "rich black mould".

Jukes (1847, I, 339) presented a schematic section through these features.

Figures 4 and 5 give Jukes's map and profile of Raine Island as surveyed in 1844. Figure 6 is a map of Raine surveyed by pacing and compass traverse in November 1973, and Figure 7 is a profile across the centre of the island surveyed at that time. The datum is inferred from the measurement of a still water level at a given time, and comparison with tide predictions for Sir Charles Hardy Islands, the nearest place for which predictions are available; the Standard Port is Cairns (Department of Harbours and Marine 1973). These data show the following topographic features:

- (a) the outer beach, generally 20 m wide and 5 m high, with intermittent beachrock;
- (b) the unvegetated beach crest, horizontal or falling slightly landwards, 20-25 m wide;
- (c) a low area of tussock grassland, varying in width from 10 to 80 m but averaging 30-40 m, with average elevation 4 m or a little less;
- (d) a cliff of cemented sandstone, of intricate outline in detail and with some isolated islands of sandstone in the tussock grassland, undercut and cavernous, generally 1-1.5 m high, with the outer edge reaching a uniform height of 6 m;

- (e) a high ridge of uncemented sand, with grass and herb cover, widest in the south (average 100 m but varying from 75 to 110 m) and narrower in the north (average 35 m, varying from 25 to 75 m), with a maximum elevation of about 9 m;
- (f) a central, unvegetated flat, with a superficially-cemented surface of white guano, with an elevation of 6 m accordant with the height of the peripheral cliff edges.

Areas of the different topographic units derived by planimetry from the map in Figure 5 are as follows:

outer beach slope	3.72 ha
unvegetated beach crest	3.23 ha
tussock grass depression	6.75 ha
high ridge crest	9.58 ha
central guano flat	4.04 ha
total area	27.3 ha

These figures do not include the area of intertidal beachrock, which covers another 0.68 ha.

### Lithology

The nature of the "coral rock" was first studied by Jukes, both at outcrop on his first visit in 1843 (Jukes 1847, I, 128) and in quarries opened during the erection of the Beacon in 1844 (1847, I, 337-340). He found that "the stone was made up of small round grains, some of them apparently rolled bits of coral and shell, but many of them evidently concretionary, having concentric coats ... not unlike some varieties of oolite in texture and appearance. It contained larger fragments of coral and shells, and some pebbles of pumice, and it yielded occasionally a fine sand that was not calcareous, and which was probably derived from the pumice. Some parts of it made a very fair building stone, but it got softer below, till it passed downwards into a coarser coral sand, unconsolidated and falling to pieces on being touched" (1847, I, 127-128). Excavations for the quarries revealed drusy cavities with gypsum, many recent shells, and one or two nests of turtle eggs (1847, I, 128, 340), as well as pumice pebbles (1847, I, 337).

In 1874 Moseley (1879, 299-300) observed that the rock was evenly bedded, the bedding being horizontal in the centre and towards the sea round the shore. On the northeast side near the Beacon he quotes a dip of seven degrees. Moseley also contrasts the white sand, consisting of shells, corals and Foraminifera, of the beaches, with the areas above high water mark, which were redder and had a consolidated crust (1879, 300).

### Stratigraphy

Two holes were dug during the *Fly* expedition in the centre of the island. One dug by Jukes to a depth of 5 ft 1 in (1.5 m) showed the following section:

0 - 6 inches ( 0 - 15 cm)	"Good black vegetable mould"
6 - 9 inches (15 - 23 cm)	"Stone, brown mottled with white, hard and coarse grained"
9 - 25 inches (23 - 63 cm)	"Rich moist black soil, like bog-earth"
25 - 61 inches (63 - 155 cm)	"Stone of a light brown colour, rather soft, but tough, and yielding slowly to the pickaxe"

(Jukes 1847, I, 127).

MacGillivray's pit the following year reached a depth of 16 ft (4.9 m), with the following section:

0 - 3 inches (0 - 7.6 cm)	"Fine coral sandstone"
3 - 12 inches (7.6 - 30.5 cm)	"Moist pulverulent black earth, resembling peat, but without any trace of woody fibres"
1 - 13 feet (30.5 cm - 3.96 m)	"Successive deposits, varying from coarse coral conglomerate to unconcreted calcareous sand mixed with a few small scattered fragments of coral and shells"
13 - 14 feet (3.96 - 4.27 m)	"Masses and large fragments of coral (of species now alive on the reef), bleached and water-worn, loosely inbedded in coarse sand"; inflow of seawater took place at this depth.

(MacGillivray 1846, 1474).

### Sediments

Sediment samples were taken from the beach slope, beach berm and high ridge on the north, west and south sides of the island; these were mechanically analysed and components identified in the fraction coarser than 250 microns. Components were classed as coral and

coralline algae, molluscs, platy Foraminifera (mainly *Marginopora*), spherical Foraminifera (including *Baculogypsinoïdes*), and *Halimeda*. All the samples are remarkably homogeneous. They lie in the size range of coarse sands (0.4 - 0.9 $\phi$ ); are well sorted (0.3 - 0.5 $\phi$ ); have near symmetrical distributions; and are mainly platykurtic. Two components dominate, molluscan fragments and spheroidal Foraminifera. Only on the leeward side do coral and coralline algal fragments contribute significantly to the coarse fraction. Molluscan fragments are more common on the beach and spherical Foraminifera on the berm and ridge, presumably because of the greater mobility of the latter. Small discrete lenses of platy Foraminifera, *Halimeda* and pumice were noted at the time of collection. Figure 8 gives sample curves for a beach (curve 1) and high ridge (curve 2) sample.

Two samples were also taken from the centre of the island, one (curve 3 in Figure 8) from the central depression, and one (curve 4) from its surrounding ridge. The central depression sample has a mean size of 1.0 $\phi$ , is moderately sorted, symmetrical and leptokurtic; it differs from the beach and berm sediments in its fine tail (coarser than 2.0 $\phi$ ). The north ridge sample is much finer (mean size 2.3 $\phi$ ), is poorly sorted (1.25 $\phi$ ), symmetrical and platykurtic. Its distribution differs markedly from that of the beach sands.

#### Interpretation and subsequent observations

Jukes (1847, I, 339-340) believed that the geology of the island could be explained by (1) the formation of a sand cay at the leeward end of the reef; (2) the formation of a crust by solution and redeposition of calcium carbonate above high water mark; (3) the cessation of accumulation and the cliffing of the lithified material; and (4) the later resumption of sand accumulation to form the present peripheral sand ridge. The age of the whole island he believed was indicated by the thickness of up to 2 ft of "vegetable mould" in the central depression. Moseley in 1874 compared the rocks of Raine with the "calcareous sand rock" or aeolianite of Bermuda, except that the former was more evenly bedded. Jukes's interpretation is largely confirmed by recent observations, though following the large-scale guano digging of 1890-92 it is no longer possible to be sure that surface features are not of human origin, at least in the central depression.

Many later interpretations, often involving sea-level changes, are less closely related to the facts of lithology and stratigraphy than was Jukes's. Rattray (1869, 303) described Raine as "consisting of hard compact brecciated coral conglomerate, with a shelving beach of coarse coralline and shelly sand, and a scanty superstratum composed of the coral debris sparingly mixed with vegetable matter, and a thin layer of guano". He suggested that the present island had been formed beneath the sea and had then undergone emergence, and he termed the island an "extinct" coral reef. Neither Jukes nor MacGillivray had described a coral conglomerate or any raised reef. Several subsequent workers accepted Rattray's inference of emergence, however, from Agassiz (1898, 124) onwards. Fairbridge (1950, 352) states that Raine



is "in part at least, an emerged beach rock. With a tidal range of 10-12 feet and an extra 2-3 feet to include mean swash, an emergence of about 10-11 feet is indicated. Rattray (1869) also mentioned a raised coral breccia here. A definitely emerged coral reef occurs some 12 miles southwest of Raine Island (Jukes 1847). It is 2-3 miles long and 0.25 miles wide, with *Porites* colonies in the position of growth 10-12 feet above the present reef growth level". Fairbridge in a later paper (1967, 403) called Raine "the only emerged reef island on the whole outer barrier; Jukes observed that it consists of a calcareous aeolianite, with an emerged beachrock terrace here ascribed to the 3 m mid-Holocene stage. The aeolianite, by analogy with other offshore occurrences in Australia ... is probably of late glacial (Würm) age, when sea level was low enough to permit wide beaches to form and dune accumulations to develop". According to Bennett (1971, 37), Raine "consists of older, solidified reef material formed at a period when the sea level was higher", and the stone used for the Beacon was "quarried out of the solid reef".

These conclusions evidently go substantially beyond the facts so well recorded by Jukes and MacGillivray in 1843-44, and are not supported by evidence collected then or observable now. The 3 m mid-Holocene "emerged beachrock terrace" of Fairbridge is not beachrock, is not emerged (in the sense of being now at a higher level with respect to sea level than when it was formed), and does not stand at 3 m. The cliff edges stand at 6 m and are accordant with the central guano flat. All the beachrock at Raine Island is at low intertidal levels, and there is no evidence that any beachrock there is raised: a radiocarbon date (ANU-1591) on a *Tridacna* valve from beachrock at spring-tide swash level is  $1180 \pm 65$  yr B.P. (Polach et al. 1978, 151). There is no evidence that the main cemented horizon which outcrops in the cliffs is an aeolianite (cross-bedding and similar sedimentary structures seem to be completely lacking), and all the evidence indicates that it is a superficial cementation phenomenon, decreasing with depth, in the way that Jukes envisaged. It is a cay sandstone in which the cement is partly phosphatic, and cementation probably represents a continuing process rather than a discrete event. The "raised reef" 12 miles southwest of Raine Island, described by Jukes and to which Fairbridge refers, was also visited in 1973: it is not a raised reef and there are no *Porites* colonies in the position of growth: it is simply a deposit of large storm boulders near the reef edge, all now much eroded, and having no significance with respect to changes in sea level.

#### Phosphate deposits

No detailed account of the Raine Island phosphates, mined in the central area in 1890-92, has been published, and no analyses of the material are known. According to Saville-Kent (1893, 120), "the deposits occur under three distinct conditions: Firstly, in layers some fifteen inches thick, immediately beneath the upper crust of coral conglomerate, which constitutes the encircling plateau described by Mr Jukes; secondly, in pothole-like hollows in the same location; and thirdly, in trench-like depressions in the central black earth basin".

The cliffs probably retain much of their original appearance, since the mining was carried out in the central flat; they closely resemble comparable cliffs on other islands with phosphatic cementation, such as Denis Island, Seychelles (Fryer 1910, 18-19, Plate 2). The cementation is greatest at higher levels and diminishes with depth; the lower surface of the cemented horizon is irregular, and forms a series of downward-directed lobes and pillars. These probably indicate differential permeability in the originally uncemented sands. T.P. Scoffin has examined specimens from the upper part of the cliffs as part of a wider study of coral island phosphates. The grains in the sands are of variable origin: Foraminifera 40%, *Halimeda* 30%, coral 10%, mollusc 10%, unknown 10%. Phosphatic cement occurs as a wavy thin film with laminated structure coating the individual grains; the grains themselves have been altered centripetally for distances of a few microns from the grain margins. The phosphate mineral is hydroxylapatite; the other main mineral present is aragonite, with a trace of calcite. The presence of aragonite suggests a young age for the material. Chemical composition is 31.0% P<sub>2</sub>O<sub>5</sub>, 54.0% CaO.

#### WATER SUPPLY

There is no standing surface water on Raine, except possibly for a few days immediately after storms. During the *Fly* expedition water was imported from Sir Charles Hardy's Islands for the men building the Beacon. Jukes (1847, II, 266) says that "one or two wells were sunk in the island, but no fresh water was procured; although in one of the wells, at a depth of 16 feet, the water was only brackish, and could be used to slack the lime, although very unpalatable to the taste". Arundel in 1890 had to construct a seawater distillation plant for his work force. Warham (1961, 78-79) also states that there is no fresh water and that "various attempts to strike it by digging in the past have failed".

A carved inscription on the inside of the walls of the Beacon, however, apparently of mid-nineteenth century date (it is mentioned in Arundel's diary in 1890), states that fresh water can be obtained at a depth of 7 feet.

#### VEGETATION AND FLORA

The vegetation of Raine Island consists of low shrubs, herbs and grasses; there are no trees. To Blackwood (1844a, 539) it was the "quantity of coarse green vegetation on it" which distinguished Raine from most of the other small sand cays in this northern reef area; he was clearly thinking of unvegetated sand cays in the vicinity, such as those on Ashmore Reef.

Jukes (1847, I, 127) described "a low shrubby vegetation, partly of reed-like or umbelliferous plants, and partly with a close green carpet of a plant with succulent leaves and stem, which we subsequently found was good to eat, and so went with us by the name of 'spinach'"

(this was probably *Portulaca*). MacGillivray (1846, 1475) gave a fuller account, though unfortunately unsupported by specimens: "Of the Botany of the islet I can give but a very meagre account, for a collection of about twenty species, found by me, unfortunately went to decay for want of a proper place of storage on board ship. Several of these species I have elsewhere observed on the main land of New Holland; among others, a long, trailing, woody plant with conspicuous yellow blossoms [probably *Tribulus cistoides*], and a large white-flowered convolvulus [probably *Ipomoea macrantha*]. Two species, very abundant, on the island, were used by us as vegetables, one of them under the name of spinach [*Portulaca*], for which it was considered a very fair substitute, and as such served out to the ship's company. Most of the plants of the island are more or less succulent; there is but one shrub, a slender Acacia, five or six feet high, with small yellow flowers [probably *Sesbania*]" . The surrounding sand area had "a few scattered tufts of grass and other herbage" (MacGillivray 1846, 1474). A variety of cultivated plants was introduced during the *Fly* expedition and during the visit of the *Heroine* in 1845; they are described later.

The *Challenger* Expedition in 1874 recorded 11 species of flowering plants, including two grasses. They noted fungi on dung, but no mosses, ferns or lichens. There was also no trace of the *Fly* vegetable gardens or of other introductions. No species list appears to have been published from these collections (Moseley 1879).

In 1910 W. Macgillivray (1910, 224) found "a coarse grass, a kind of pig-face weed, and a low perennial shrub of horizontal growth, not more than 1 to 1½ feet from the ground anywhere, and bearing grey-green leaves and a yellow flower". These were probably *Lepturus repens*, *Portulaca* sp., and *Tribulus cistoides*, respectively.

In February 1959, after good rains, Warham (1961, 78) found only six species of flowering plants, "the principal one being a kind of mallow (*Abutilon graveolus* or *indica*) which was flowering, a spinach-like amaranth (*Amaranthus viridis*) and a low bushy plant *Tribulus cistoides*. This bore orange flowers and is probably the 'acacia' of the early visitors of the island [*Abutilon* and *Tribulus* appear confused in this account]. Two grasses also flourished: *Eleusine indica*, an introduced species, and *Lepturus repens*, a native plant. This grew quite thickly on the dunes on the south-east side of the island. A low succulent also grew around the edges of the central depression [probably *Portulaca* sp.]. None of these plants was more than two feet high".

The only published list of Raine Island plants appears to be that of Hindwood *et al.* (1963, 44), based on collections made in November 1961 and lodged in the Queensland Herbarium, Brisbane, and the Division of Plant Industry, C.S.I.R.O., Canberra. Six species are recorded, and it is likely from Warham's records two years earlier that others were missed.

Plants were collected in 1973 and were identified by Miss S. Reynolds at the Queensland Herbarium, Brisbane. The following list includes the plants cited by Hindwood *et al.* (1963).

Gramineae

*Eleusine indica* (L.) Gaertn.

Stoddart 5061. Also cited by Warham (1961, 78).

*Lepturus repens* R.Br. cf. var. *repens*

Stoddart 5051, 5059. Also cited by Warham (1961, 78) and Hindwood *et al.* (1963, 44).

Nyctaginaceae

*Boerhavia* sp.

Stoddart 5054 (specimen lost). Hindwood *et al.* (1963, 44) also cite *Boerhavia tetrandra* Forst., but the specimen collected in 1973 is not this species.

Amaranthaceae

*Achyranthes aspera* L.

Stoddart 5053. Cited by Hindwood *et al.* (1963, 44).

*Amaranthus viridis* L.

Stoddart 5057, 5058? Warham (1961, 78) also cites *Amaranthus viridis*.

Portulacaceae

*Portulaca oleracea* L. (*sensu lato*)

Stoddart 5056. Possibly the plant mentioned by W. Macgillivray (1910, 224) and Warham (1961, 78).

Cruciferae

*Coronopus integrifolius* Spreng.

Stoddart 5060

Leguminosae

*Sesbania* cf. *aculeata* Poir.

Stoddart 5050. *Sesbania aculeata* is cited by Hindwood *et al.* (1963, 44).

Zygophyllaceae

*Tribulus cistoides* L.

Stoddart 5055. Cited by Warham (1961, 78) and Hindwood *et al.* (1963, 44); possibly the plant mentioned by MacGillivray (1846, 1475).

Malvaceae

*Abutilon asiaticum* var. *australiense* (Noch. ex Britt.) Fosb.

Stoddart 5052. Cited as *A. indicum* (L.) Sweet by Hindwood *et al.* (1963, 44); probably the plants mentioned by W. Macgillivray (1910, 224) and Warham (1961, 78).

## Convolvulaceae

*Ipomoea macrantha* R. and S.

Not collected in 1973 or by Hindwood *et al.* (1963).  
Possibly the plant mentioned by MacGillivray (1846, 1475).

## INVERTEBRATES

Most of the collections of invertebrates made at and near Raine Island have been of marine animals during the *Challenger* Expedition. These are listed by Murray (1895, 682-688); they comprise mainly species of Ostracoda, Mollusca and Foraminifera, with only a few land or shore animals.

The most conspicuous, indeed the only, semi-terrestrial crustacean is the ghost crab *Ocypode*. Moseley collected a single male specimen of *O. ceratophthalma* (Pallas), recorded by Miers (1886, 238-239). In 1973 the population was predominantly *O. ceratophthalma* with a few *O. cordimana* Desmarest, the two species being represented in a sample of 60 individuals in a ratio of 6.5 : 1. Coenobitid hermit crabs, elsewhere common on guano islands in the central Pacific and Indian Oceans and also in the Caribbean, appear to be completely absent on Raine and other Great Barrier Reef islands. Mole-crabs of the genus *Hippa* inhabit the coarse sands of the lower beach levels; although *H. pacifica* (Dana) was the only species collected in 1973, it seems likely that *H. celsa* (de Man), a commoner species on other reef islands in the region (see Gibbs 1978), is present also.

Among insects, MacGillivray (1846) noted a large scarab, Coleoptera including *Hister*, *Necrobia* cf. *ruficollis*, and *Dermestes murinus*; *Pimelia*; and ixodid ticks. Moseley (1879, 302) found an earwig *Forficula* under stones and a very common locust *Acridium*. No further invertebrate collections appear to have been made.

## MARINE TURTLES

The Green Turtle nesting season at Raine Island is concentrated from October to December; visitors outside these times have usually made few turtle observations. Parsons (1962) in his standard work on the Green Turtle makes no mention of Raine Island, and while Bustard (1972) includes Raine Island in a map as an important nesting site he makes no mention of it in his text. Yet Raine is certainly one of the largest Green Turtle nesting sites in the world, and could be the largest remaining still undisturbed by man.

Jukes's first visit in July 1843 produced few records. "There were a few turtle tracks on the beach, but we did not succeed in taking any, though many dead ones were scattered about the island", especially at the foot of the cliff (Jukes 1847, I, 130). During the 1844 visit, MacGillivray (1846, 1479) found that "during the months of June, July and August, the turtle occurred at irregular intervals, generally

singly, but in the beginning of September they became more numerous". In the following year a party from the *Bramble* found the cliffs and quarries "full of the remains [of turtles] ... who had fallen over on their backs and perished miserably". They took 14 turtle by turning them on the beaches at night, some of them being of 250-300 lbs weight (roughly 110-140 kg). Sweatman (MS, 94-95) gives a graphic account of taking turtle during this visit. Mackenzie (1845, 494), calling with the *Heroine* on 25 January 1845, "obtained fourteen large turtles, each averaging four cwt [ca 200 kg]". In August 1874 the *Challenger* found only the carapaces of numerous dead turtles (Moseley 1879, 302).

Conversely, Macgillivray (1910, 224), on 30 October 1910, found "great numbers of turtles ... on the beach and in the shallow water round the boat". On 4 December 1913 he found that "about thirty turtles were crawling up the beach near where we landed, and the shallow water contained hundreds of them", coming ashore at night to nest (Macgillivray 1917, 67).

During the *Fly* visit, MacGillivray (1846, 1478-1479) noted that all the turtle seen were Green, *Chelonia mydas*, and that they laid clutches of at least fifty eggs. He found that the hatching young suffered predation by frigate birds and sooty terns, and sixty years later Macgillivray (1917, 84) recorded predation of eggs by Crested Tern *Sterna bergii* and Silver Gull *Larus novae-hollandiae*.

Green Turtle were nesting during the visit to Raine Island in 1973. Tracks were counted round the island each morning. Measured at the foot of the beach, the perimeter of the island occupied by sand (including the low and discontinuous narrow beachrock of the northern coast) totals 1600 m, and that occupied by beachrock 500 m (76 and 24% respectively). Numbers counted on the beach only were as follows:

	<u>Tracks</u>	<u>Animals</u>
Night of 31 October	324	162
1 November	245	123
2 November	230	115
3 November	270	135

During the night of 3 November, animals were also counted on the nest both on sandy beaches and also inland from beachrock shores. The ratio of tracks:animals on the beaches can then be used to infer the number of tracks which might be expected on the beachrock shores, to give an estimate of the total number coming ashore for the whole island on that night. The results are:

	<u>Beach</u>	<u>Beachrock</u>	<u>Whole island</u>
(a) Animals counted on nest	87	38	125
(b) Numbers inferred from tracks	135		
Ratio (b):(a)	1.55		
Inferred total numbers	135	59	194

In subsequent surveys, Birtles (1978) estimated the numbers of nesting turtles at 11,800 in 1974, 50 in 1975, 1000 maximum in 1976, and 50-100 in 1977. Kowarsky (1978) also made ground and aerial observations in January 1976, but although tracks were numerous he could not make any estimate of numbers. For comparison, at Ile Europa, Mozambique Channel, sometimes stated to be the largest Green Turtle colony in the world, Hughes (1974) estimated 5,000 emergences a year, and Servan (1976) 1300 a year.

The prime nesting habitat on Raine is the unvegetated sand areas of the beach crest, though a considerable number of turtles do nest in the outer *Lepturus* tussock grassland between the beach and the cliffs. Planimetric measurements on Figure 5 indicate a total area of unvegetated beach crest of 32,300 sq m. A turtle 1 m long requires an area of not less than 1.54 sq m for its nesting depression. Hence there are approximately 21,000 potential non-overlapping nest sites in the beach crest area. Two hundred turtles nesting in one night would have 161.5 sq m each in which to choose a nesting site. Each site would have roughly 1 chance in 100 of being selected. These calculations give some idea of the possible potential size of the Raine Island colony. Elsewhere on the Great Barrier Reef, on vegetated islands, the size of nesting area available is a limiting factor in the number of successful nestings (Bustard and Tognetti 1969): at Raine Island this is unlikely to be so. Kowarsky (1978) quotes a clutch size at Raine of  $105.8 \pm 22.0$  eggs ( $n = 6$ ).

The curved carapace length of females on the nest was also measured on the night of 3 November, and Figure 9 presents a histogram of the results. 124 animals were measured. The mean length was 109 cm, standard deviation 5.29 cm; the smallest measured was 90 cm long, and the largest 122 cm. Bustard (1972, 138-141) quotes average figures of 107 cm curved length for Great Barrier Reef Green Turtles, and ranges of 89-127 cm. Curved length can be converted to straight length using the formula derived for Aldabra turtles by Frazier (1971, 390), and the calculated straight lengths then used to compare populations in different parts of the world. The Raine Island turtles are very similar in size to those of Aldabra, markedly bigger than those of Ceylon, Yemen and Sarawak, and markedly smaller than those of Guyana, Ascension Island and Surinam (data listed by Frazier 1971, 380, and Servan 1976, 424). In addition to the 1973 data, Kowarsky (1978) gives mean straight length of  $100.2 \pm 5.5$  and mean curved length  $108.6 \pm 5.1$  cm for four individuals at Raine Island.

While measuring the turtles in 1973 it was observed that animals differed markedly in degree of curvature of carapace. In some the curvature was so shallow that it is possible they belong to *Chelonia depressa* Garman, the Flatback Turtle (Bustard 1972, 74-88) rather than to *Chelonia mydas* L.

According to Limpus (1978), tagged turtles from Raine Island have been recovered from south of Cooktown, Queensland, through the Torres Strait and southern Papua New Guinea to Aru Island, Indonesia.

In addition to the Green Turtle, Boulenger (1889) also records the Hawksbill *Eretmochelys imbricata* (as *Chelone imbricata*) from Raine, but no subsequent records are known.

#### BIRDS

Raine Island is a major breeding station for seabirds, and probably the most important in terms of numbers of species on the Great Barrier Reef. It has large breeding colonies of Brown and Masked Gannets, Noddies, Sooty Terns, and Wedge-tailed Shearwaters. It is also a breeding site for the Red-tailed Tropic-bird and the Lesser Frigate-bird, otherwise rare on the Great Barrier Reef. There are no comparable seabird-breeding stations (except for colonies of Noddies and Sooty Terns) between Raine and the Capricorn and Bunker Islands at the southern end of the Reef. There is also a resident land bird, the Banded Landrail, many shorebirds, and a number of migrants and vagrants recorded.

The first ornithological observations were those of Jukes and MacGillivray in 1843-44 during the visits of the *Fly*. Moseley made observations and collections during the *Challenger* visit in August 1874. The first extensive records are those of MacGillivray and M'Lennan in 1910, 1911 and 1913. The most detailed account of Raine Island birds is that of Warham (1961), following his visit in February 1959. Warham's list is used as the basis for the present account, though nomenclature follows Storr (1973); we are most grateful to C.W. Benson for his assistance with and comments on this list. Following Warham, K.A. Hindwood and others also visited Raine during a survey of seabirds of the Coral Sea in November 1961; their records are also incorporated here.

In addition to the birds listed here, Ellis (1937, 179) also records "several long-legged and long-billed ibises", "three common crows", and "several diminutive hawks". MacGillivray (1846) also records several species of uncertain synonymy, including *Charadrius virginianus*, *Thalasseus strenuus*, *Callocalia arborea*, and *Porzana*.

*Ducula spilorrhoe spilorrhoe* (Gray) Torres Strait Pigeon

One migrant bird is recorded (as *Myristicivora spilorrhoe*) by Ellis (1936, 178).

*Rallus philippensis yorki* (Mathews) Banded Landrail

Recorded as *Rallus philippensis*? by MacGillivray (1846, 1476-77) in 1844, and subsequently figured by Gould (1848, VI, 76). It was "very abundant all over the island", under vegetation, beneath overhangs, and in shearwater burrows. MacGillivray found it very wary, though it ran and rarely flew. He caught "great numbers" (up to 45 in a day) with his dog.



In 1874 Moseley collected two males and one female (Forbes 1878). Under the name *Rallus pectoralis* Moseley described it as tame, and easily knocked down with sticks or caught by hand. In August there were full-fledged young (Moseley 1879, 301). On the basis of this record Kikkawa (1976) lists *R. pectoralis* Lewin Water Rail as a separate species (but see discussion below).

During 1890-92 there were initially large numbers, but "a welcome addition to the table they were. Their numbers were materially lessened during our occupation of the island, but some were left to carry on the restocking" (Ellis 1937, 177-178). Macgillivray in October 1910 simply records "numbers" running over the island (1910, 226).

There are no further records until Warham's visit in February 1959. It was then "very numerous and ... often seen in the daytime skulking among the herbage or running about beneath the caves and cavities under the cliffs. At night they spread out all over the island and were often seen on the dunes where they fed on turtle eggs exposed by the subsequent diggings of other turtles. ... Two nests were discovered ... their eggs being hidden beneath the thick herbage" (Warham 1961, 83). Warham also noted that the rails could be approached closely at night. The description agrees with the situation in 1973, except that dead birds were numerous on the ground, both on the high ridge and beneath the cliffs. Several of these dead birds were collected. Two males were also collected by Hindwood *et al.* (1963, 38) in November 1961; one is in the Western Australian Museum (no. A8755) and the other in the C.S.I.R.O. collection (no. CSIRO 301).

Storr (1973) states that *R. p. yorki*, a small, dark race, is very common in the Torres Straits islands and on low islands of the Queensland coast from Pandora Cay to Lady Musgrave Island (in 1973 we observed rails on Hope Islands, Turtle Islands, Three Isles, and Pelican Island). A second race, *R. p. pectoralis*, is of uncertain status but evidently rare in Queensland. The pectoral band in *yorki* is darker (chestnut cinnamon rather than pale cinnamon) and narrower (6-10 mm wide rather than 14-30 mm). C.J.O. Harrison has kindly re-examined specimens from Raine Island in the British Museum (Natural History), together with those taken as dead birds in 1973. The three *Challenger* specimens which included a young bird, suggesting recent breeding, are of the southern race, *pectoralis*. S.A. Parker has examined Raine Island specimens in Australian museums, and found them to be *yorki*, and the specimens taken in 1973 were also of this form. Harrison comments: "It seems probable from the evidence that both Australian races are migratory to some degree, and that both could potentially occur in Raine Island in passage. There are other references in literature to the species breeding on the island but no subspecific recognition of them. There is no clear indication of the status or origin of the birds which do or did (intermittently?) breed on the island. Dead bodies might be those of failed migrants."

*Gallinula porphyrio melanotus* (Temminck)

Eastern Swamp-hen

This common Torres Strait migrant is named (as *Porphyrio melanotus*) by Warham (1961) from an observation by Ellis (1936). Ellis refers to "some game-birds with dark blue plumage, a patch of white below the tail, strong red beak, and long red legs and feet ... known as pukekos in New Zealand", which were seen on "several occasions" (Ellis 1936, 179).

*Diomedea chrysostoma* Forster

Grey-headed Albatross

This is listed for Raine Island by Kikkawa (1976) on the basis of a reference by Hull (1925). Hull saw a bird near Lizard Island in June 1924 which "answered fairly well to the description of *Diomedea chrysostoma*, except for the neck shading. The mate ... a Filipino, said he had seen a similar bird at Raine Islet ..." (Hull 1925, 15). This is clearly an uncertain record.

*Puffinus pacificus* (Gmelin)

Wedge-tailed Shearwater

In May 1844 MacGillivray (1846, 1478) noted (as *Puffinus* -----?) "a small colony of these birds among some rank herbage which concealed the entrances to their burrows, in which they were easily caught ... it is possible that they are, in a great measure, nocturnal" as at Heron Island.

Under the name *Puffinus sphenurus*, Macgillivray and M'Lennan made several observations during 1910-1913. In October 1910: "At the north-western end of the island many burrows of a Petrel are found. We dug out several to a depth of 4 or 5 feet, and found them to contain either one or a pair of birds (*Puffinus sphenurus*). There are no eggs. It seems that the birds are only cleaning out their burrows and will probably lay in a month's time" (Macgillivray 1910, 226). In July 1911 the shearwater was again "in its burrows". M'Lennan "obtained several skins, and noted that each burrow contained two birds. He visited the burrows after dark, and waited for some time, and saw only one bird leave, but could hear mournful calling in all directions. A male and female in each burrow" (Macgillivray 1914, 141). In December 1913 Macgillivray (1917, 83-84) noted "many burrows", some 6 ft long, in the centre of the island, most with one egg and some with downy young.

In February 1959 Warham (1961, 80, 83) found "some hundreds of burrows", with "large young in down, some with feathers 1.25 inches long on the wings". In November 1961 Hindwood et al. (1963, 38) noted breeding, without further detail. In 1973 inhabited burrows were concentrated on the high ridge at the western end of the island.

This colony of shearwaters is the only one on the Great Barrier Reef north of the Bunker and Capricorn Island (Lavery and Grimes 1971; Serventy et al. 1971, 124). At the Heron Island colony, birds are present from October to April (Moulton 1961). In 1960 the first birds

arrived at Heron Island on 8 October, and the first eggs were laid on 15 December. Each day the birds left the island at 5 a.m. and returned at 7.45 p.m. (Gross, Moulton and Huntington 1963).

*Pterodroma arminjoniana heraldica* (Salvin) Trinidad Petrel

Recorded for the first time in Australia and photographed on 22 February 1959 by Warham (1959, 1961; Serventy *et al.* 1971). Warham also found an egg which may belong to this bird.

*Fregata minor* (Gmelin) Greater Frigate-bird

There are several early references to this species on Raine Island, possibly in error for *F. ariel*. Storr (1973, 8) states that *minor* apparently breeds in Torres Strait, while *ariel* breeds on Rocky Island (Gulf of Carpentaria), Raine Island, and 'Gillett Cay', Swains Reefs, in the southernmost sector of the Great Barrier Reef, April to August. Bennett (1971, 60) figures juvenile birds on the nest at the latter location. Serventy *et al.* (1971, 155) state that *minor* is not known to breed at Raine Island. It is normally a tree-nesting species, and thus might not be expected there, though small numbers are found on treeless islands in the Phoenix Group, Central Pacific.

*F. minor* is recorded from Raine Island as *F. aquila* by MacGillivray (1846), quoting Lt J.M.R. Ince. Specimens were said to have been sent to Gould, but they are not mentioned by Gould (1865). *F. minor* is also mentioned during the *Challenger* visit by Tizard *et al.* (1885), and one male and four females were so identified by Sclater and Salvin (1878, 650) as collected by the *Challenger* on 31 August 1874. These specimens were, however, cited as *F. ariel* by North (1912, 353), and they were also so listed by Ogilvie-Grant (1898, 449). Two of the specimens, in the British Museum (Natural History), have been found and re-examined by C.W. Benson, who confirms them to be *ariel* and not *minor* (see next species).

Warham (1961, 83) in 1959 saw 4-5 birds identified as *F. minor*, all apparently adult females. It was possible that an area of 40 empty nests might belong to this species, since these were on the ground and all the *ariel* nests he saw were on bushes. There is, however, no breeding record of *F. minor* yet for Australia. Lavery and Grimes (1971) cite Raine as a possible breeding site for this species, but its status there remains to be established.

*Fregata ariel* Lesser Frigate-bird

Raine Island is one of only two Great Barrier Reef breeding localities for this species (Lavery and Grimes 1971). In July 1843 Jukes (1847, I, 129) found "young of all ages". In May 1844, MacGillivray (1846, 1478), under the name *Atagen ariel*, reported "small colonies of about a dozen individuals. Its nest is formed of small dry twigs, raised about a foot from the ground, or sometimes placed upon a tuft of herbage, a foot in diameter"; he noted one egg.

Ince (in Gould 1848, VII, 72) described it "breeding in colonies at its S.W. corner; the nest being composed of a few small sticks collected from the shrubs and herbaceous plants which alone clothe the island, and placed either on the ground or on the plants a few inches above it. The eggs ... generally one, but occasionally two". Ince found stages from fresh eggs to 2-3 week hatchlings. Stomach contents comprised young turtles, squid and crabs.

In August 1874 the *Challenger* found 30-40 nests with young well advanced (mostly in the air) but no eggs. All the nests were in a small patch near the cleared area, and consisted of compact platforms of twigs and grass 8 inches in diameter raised on bushes above the ground surface (Moseley 1879, 301-302; Sclater and Salvin 1878). The identity of these birds has been discussed under the previous species. Two specimens were re-examined by C.W. Benson at Tring:

- No. 80.11.18.119: adult male, no date  
 No. 80.11.18.442: young bird still partly in down, no date.

Both are *F. ariel*, as listed by Ogilvie-Grant (1898, 449).

In October 1910 Macgillivray (1910, 226; North 1912, 355) found 50 feathered young on the east side of the island near the centre, presumably from eggs laid in May-June. The nests were flat platforms of sticks and grass 4-6 inches above the ground. In July 1911 M'Lennan found 150 nests: "Several colonies of Frigate-birds were seen near the beacon ... They were eight in number, of from three to thirty nests. I counted 150 nests altogether, several of which contained one egg each; two of these were on the point of hatching. The rest of the nests contained one young bird each, in all stages of plumage, from a couple of days old to birds ready to fly" (Macgillivray 1914, 148). In December 1913 nesting was over; fledged young were all over the island and soaring in the air. Macgillivray (1917, 181-182) took and described one male and one female specimen.

Warham in February 1959 estimated the population at 2000, many possibly from elsewhere, and counted about 150 nests. There were no eggs. The young were all able to fly though three or four still spent all day on the nest. 80 per cent of the 500 birds in the air during the day were juveniles. Each bird on the ground was perched on a dwarf shrub of *Abutilon* or *Tribulus*. The frigates were seen harrying Red-footed and Masked Gannets, and also fishing. Warham (1961, 80, 84; Serventy *et al.* 1971, 156) also gives notes on behaviour. Hindwood *et al.* (1963, 39) confirmed the breeding and collected one female in November 1961 (Queensland Museum No. 0.9135).

In November 1973 adult males and females were numerous both perched on the parapet of the Beacon and soaring in the air at the east end of the island. There were two concentrations of juveniles not yet flying: one of about 120 birds on a mound in the central guano flat (Figure 5), and another of about 65 juveniles immediately to the north, on the *Lepturus* tussocks between the cliff and the beach crest. Ogilvie

(1975) estimated the population at 300-500. For notes on diet, see under *Sula leucogaster*.

*Sula leucogaster plotus* (Forster)

Brown Gannet

There are several large colonies of Brown Gannets on the Great Barrier Reef islands, including those on Ashmore Banks and Pandora Cay near Raine Island, and on Raine Island itself (Lavery and Grimes 1971, Serventy et al. 1971, 172).

In the 1840s, however, numbers were apparently small. Jukes (1847, I, 129) in July 1843 found a few with young, forming a flock nesting separately from the Masked Gannet. In May 1844, under the name *Sula fiber*, MacGillivray noted: "The well-known brown booby breeds upon Raine's Islet, but in small numbers, as I found its nest there only once" (MacGillivray 1846, 1478). Specimens, presumably MacGillivray's, were reported as *Sula fusca* by Gould (1848, VII, 78), and there is a specimen (10/Sul/2/C/6) marked 'Blackwood Collection' in the University Museum of Zoology, Cambridge (C.W. Benson, pers. comm.). Moseley collected a male in August 1874 (Sclater and Salvin 1878, 651) and described "a slight nest of green twigs and grass on the ground" (Moseley 1879, 301), but gives no indication of abundance.

By the time of Macgillivray's first visit on 30 October 1910, however, ninety per cent of the nesting birds consisted of this species. In July 1911 M'Lennan found them all over the island, and Macgillivray described them "in thousands all over the place" (1917, 181). At the time of his October visit there were eggs, naked young, young in down, and young fledged. Most clutches were of two eggs, variable in size and shape. MacGillivray noted that in these cases only one survived, probably because of the initial difference in size of the hatchlings. The nest was simply a depression in the sand, 3-4 inches deep and 8-12 inches in diameter, with a few sticks surrounding it (Macgillivray 1910, 224). In July 1911 there were several nests with one egg, eight with two, but no hatched young, and nesting had clearly only just begun (Macgillivray 1914, 148). In December 1913, nesting was finished, very few eggs were left, and there were young birds everywhere (Macgillivray 1917, 181). Further observations by Macgillivray, with a photograph, are given by North (1912, 351-353).

In February 1959 it was again the most plentiful bird: Warham (1961, 80) estimated a total population of 7,000-9,000. He saw only two sets of eggs; the young were mostly in down, feathered or flying, but still fed by their parents. In addition to birds on the nest there were about 2,000 birds roosting on the beaches in lines facing the sea. Warham notes various aspects of behaviour and draws attention to the difference in call between male (hissing) and female (a deeper call).

In November 1961 Hindwood et al. (1963, 21; Hindwood 1964, 309) estimated there were at least 2,000 pairs. The nests contained well-incubated eggs or very small nestlings, and there were a few large downy

young. Most of the birds were in the central bare area. The differential survival of larger nestlings in a clutch of two was again noted.

The Brown Gannet was the most abundant nesting seabird in November 1973. Most of the birds were on the central flats. The nest was a slight depression, often broken through the surface crust, surrounded by twigs. Breeding was in the stage described by Hindwood in November 1961, except that few nests had young. In a count of 100 nests, 45 contained a single egg and 55 two eggs. Four contained hatchlings. Counts were made of birds on the ground at midday on 3 November in five sample areas of the central guano flats (Figure 5). These areas totalled 2370 sq m, or 5.9 per cent of the area of the flats. 162 birds were present, giving a mean density in the sample areas of 6.8 per 100 m<sup>2</sup>. Extrapolating these figures to the whole of the central flats gives a total number of birds of 2764. This figure does not include adult birds absent while feeding, birds in the air as a result of our own presence, or birds in the high-ridge grasslands surrounding the flats. Details of the counts are given in Table 2. Data given by Nelson (1970) suggest a mean nesting density of 15 birds (7.5 pairs) per 100 m<sup>2</sup>, with some colonies very much more crowded. The largest colony recorded by Nelson is of 8,000-10,000 birds; our figures suggest a total population half this size, and probably rather more than the 2,000 pairs estimated by Hindwood in 1961. Since our visit P. Ogilvie (1975) has estimated the population at 2,000-3,000.

Collections were made of regurgitations produced by adults of the gannets *Sula dactylatra* and *S. leucogaster* and the young of the lesser frigate *Fregata ariel*. The diet of the gannets appeared to be chiefly fish, with the exocoetid *Cypsilurus melanocercus* (Ogilvy) forming the predominant element, but a few small individuals (mantle length less than 10 cm) of the ommastrephid squid *Symplectoteuthis oulaniensis* (Lesson)<sup>1</sup> were noted. Similar small-sized specimens of this squid formed the bulk of diet of the young frigate birds. The importance of both the Exocoetidae and the Ommastrephidae in diets of birds in the Pacific has been discussed by Ashmole and Ashmole (1967).

---

1. The nomenclature of the forms of the 'species' *Symplectoteuthis oulaniensis* remains to be elucidated. The specimens taken on Raine all lack light organs (yellow patches) on the dorsal surface (see Clarke 1965) and thus correspond to the species A of Ashmole and Ashmole (1967).

Table 2. *Sula leucogaster* and *Sula dactylatra* in sample areas of the central guano flat, midday, 3 November 1973.

Sample area	Area, sq m	<i>Sula leucogaster</i>		<i>Sula dactylatra</i>	
		Number	Density/100 m <sup>2</sup>	Number	Density/100 m <sup>2</sup>
A	570	40	7.018	16	2.807
B	550	32	5.818	9	1.636
C	460	32	6.957	5	1.087
D	390	28	7.179	8	2.051
E	400	30	7.500	3	0.750
Total	2370	162	6.835	41	1.730

The sample areas cover 5.86% of the 40,440 sq m of the central guano flats. Extrapolation from the mean measured densities gives total numbers of 2764 *Sula leucogaster* and 699 *Sula dactylatra*.

*Sula sula rubripes* Gould

Red-footed Gannet

Under the heading "*Sula* -----?" MacGillivray (1846, 1478) described "a small species of gannet, which we named provisionally the 'white booby'. Its change of plumage are remarkable and puzzling. Early in June, this species, the young having been for some time able to fly, forsook the island during the day, returning at night to roost in a large body of several hundred". Gould (1848, VII, 79) reported this species as *Sula piscator*, breeding in "great numbers", and quotes MacGillivray's estimate of a population of "several hundreds". He also notes the variable colour. MacGillivray's specimen was later described as *Sula nicolli* by Grant and Mackworth-Praed (1933), distinguished by red feet, ash-brown upper parts, white rump and tail, but Murphy (1936) considered it to be only a colour phase of *Sula sula*, and Warham (1961) agrees. Moseley collected a female in August 1874, and this was reported as *S. piscator* in Sclater and Salvin (1878, 652). Moseley (1879, 301) described "one or two of its nests made in the bushes, like those of the noddies, raised six inches from the ground".

More information comes from the visits by Macgillivray and M'Lennan. In October 1910 Macgillivray (1910, 225) found "nests in groups in different parts of the island. All of the nests are placed on the horizontal shrubby growth, and are a clear foot or more from the ground. The nest consists of a substantial interwoven platform of sticks, about 8 to 12 inches in diameter, depressed to about an inch in the centre for the reception of the single egg". The young were then fully fledged and many roosting. In July 1911 M'Lennan found "great numbers"

building nests, several nests with one egg each, and a few with young (Macgillivray 1914, 148). In December 1913 a few stragglers were still nesting. A few nests had one egg, more had young, but the rest had left the nest. Macgillivray believed that the colour changes were age colour phases (1917, 180-181). Other observations by Macgillivray, with a photograph taken in October 1910, are given by North (1912, 348-349).

Warham (1961, 80) estimated the population as 300 in February 1959. Nesting was then over; he saw one egg and two pairs with downy young, and inferred that the breeding season lasted from June to January. The nests were built 2 ft from the ground on what he termed *Tribulus* bushes. He also found large roosts along the south side of the island, mostly in low shrubby bushes six inches from the ground or in thick grass. Most of the day is spent at sea, and the birds appear during the late afternoon. Warham also describes the colour phases. Hindwood et al. (1963, 38, 41) collected two females (C.S.I.R.O. numbers 299, 300).

In November 1973 there were two areas with Red-footed Gannets. One on the high ridge at the northwest end of the island, with about 50 birds during the day, consisted of nests on low *Abutilon* bushes 1-2 feet above the ground. Many of the nests had young in down. Another area on the high southern ridge comprised about 100 roosting birds during the day (Figure 5). Ogilvie (1975) estimated the population at 150.

According to data given by Lavery and Grimes (1971) and Serventy et al. (1971, 173-5) this small colony on Raine Island is the only breeding station for the Red-footed Gannet on the Great Barrier Reef.

*Sula dactylatra personata* Gould

Masked Gannet

Jukes (1847, I, 128) found a few with young in July 1843. MacGillivray (1846, 1478) reported it, as *Sula personata*, as "never very numerous" and said it left the island entirely during the day. Gould (1848, VII, 77), however, quoting Lt J.M.R. Ince, referred (again under *S. personata*) to "considerable numbers". Moseley gives no indication of abundance in 1874, but collected two females (*Sula cyanops* in Sclater and Salvin 1878, 652); he described the nest as "a circular hole in the earth, about 1½ inch deep" (Moseley 1879, 301).

In October 1910 Macgillivray found them nesting "promiscuously all over the islet" (Macgillivray 1910, 225), with fresh eggs, hatching eggs and young (Macgillivray 1917, 180). He reported that the nests "differ in no wise" from those of the Brown Gannet, except of course that there are no surrounding twigs. On 10-15 July 1911 M'Lennan found a few nesting sites but no eggs; one egg was laid during his visit (Macgillivray 1914, 148). In December 1913 nesting was almost over and only one nest had eggs (*S. cyanops* in Macgillivray 1917, 180). Further information is given from Macgillivray's 1910 visit by North (1912, 344-345), including a photograph. The nest depressions were



said to be 3-4 inches deep and 8-12 inches in diameter. Two-thirds of the clutches were of two eggs.

Warham (1961, 80-82) estimated the population in February 1959 as 400-500. The birds were found only in the central depression. Many of the nests had eggs or small young, and there were also downy chicks and flying juveniles. He inferred a breeding season from July to March. In contrast to the Brown Gannet, very few Masked Gannets roosted on the beaches. As with the Brown Gannet there is a sexual difference in call, the male whistling and the female more raucous. The nest is simply a depression in the sand, with no twigs. He noted differential survival of the larger bird in clutches of two. During the day many birds were at sea, and the number on the island increased during the night. Hindwood *et al.* (1963, 34) estimated the population at about 1000 pairs in November 1961.

The Masked Gannet was numerous on the central flats in November 1973, though less abundant than the Brown. Counts of birds on the ground were made at midday on 3 November in the five sample areas shown in Figure 5; details are given in Table 2. There were 41 birds in the 2370 sq m sampled, giving a mean density of 1.73 per 100 sq m. Extrapolation at this density gives a total number of 699 birds for the whole of the central flats, or about one quarter the number of Brown Gannets present. This figure excludes birds at sea or temporarily in the air, or in areas other than the central flats. The total is consistent with the estimate of Hindwood *et al.* (1963), also in November, and with Ogilvie's (1975) subsequent estimate of 800-1000 birds. The mean density is close to that reported for Masked Gannet colonies at Kure and the Galapagos Islands by Nelson (1970), and the colony is large in terms of the size ranges Nelson cites. Of 100 nests counted in 1973, 47 contained one egg or young and 53 two eggs or young. 35 per cent of the nests contained young. A marked size disparity was noted in clutches of two. For notes on diet see under *S. leucogaster*.

According to Lavery and Grimes (1971) and Serventy *et al.* (1971, 175-177) Raine Island is the main breeding station of this species on the Great Barrier Reef, with a further large colony at nearby Pandora Cay and another in the far south on Masthead Island. The colony is comparable in size with the colonies on Phoenix, Enderbury and McKean Islands in the Phoenix Group.

*Pelecanus conspicillatus* Temminck

Australian Pelican

Ellis (1937, 178) saw one bird during 1890-92. The nearest breeding station is on Pelican Island, 255 km to the south (personal observation, 1973); Serventy *et al.* (1971, 183) also record a breeding colony near Thursday Island, Torres Strait, 225 km to the north.

*Phaethon rubricauda* Boddaert

## Red-tailed Tropic-bird

This species is generally absent from the South Pacific, and Raine Island as its only known breeding station in eastern Australia, other than on sand cays in the Coral Sea (Serventy *et al.* 1971, 160).

MacGillivray (1846, 1477-1478) recorded it as *Phaeton phaenicurus* (cf. Gould 1848, VII, 73). He caught about a dozen beneath the low cliffs; there were no nests, but two were sitting on eggs. Two or more were always hovering over the island. There are two specimens (10/Phae/1/C/9, 18) collected in September 1844 in the University Museum of Zoology, Cambridge (C.W. Benson, pers. comm.). In 1874 Moseley collected a young female - "the only one seen on the island". This was reported as *P. aethereus* (i.e. the Red-billed Tropic-bird, not the Red-tailed) by Sclater and Salvin (1878, 651), and Lord George Campbell also stated that "we saw no red-tailed ones" (Campbell 1876, 162). Ogilvie-Grant (1898, 453), however, lists the Moseley specimen as *P. rubricauda*. C.W. Benson has re-examined the specimen and comments that "this identification seems correct. The bird is fully feathered but not fully grown. It lacks the long tail-feathers of adults, and the bill is also smaller (it measured, from base of skull, 66 mm) and black rather than red in colour".

Macgillivray (1910, 227; 1914, 148) saw none in October 1910. M'Lennan, however, in July 1911, found a total of seven nests, three having one egg and the rest with young. These included three nests on the 9th (one with 1 egg and two with 1 young), two nests on the 10th (one with 1 egg, one with 1 young), and one nest on the 15th (with 1 egg) (Macgillivray 1914, 148-149). Macgillivray (1917, 182-183) found them still nesting in December 1913, all except one with young. In February 1959 Warham again found seven pairs nesting, six with large feathered young, and the other with an egg. Up to twelve birds were seen in the air during the afternoons. Hindwood *et al.* (1963, 27; Hindwood 1964, 309) found six pairs in November 1961. Two females were collected (Queensland Museum No. 0.9133; C.S.I.R.O. no. 298). Several nests were seen in 1973, either in hollows beneath the cliffs or beneath large beachrock slabs. No eggs were found, but large feathered young were present. Two or three birds were generally in the air over the island. Ogilvie (1975) found 23 nests, some with eggs, and gave the population as more than 25.

Storr (1973) lists only this species as present on Raine Island.

*Hydroprogne caspia* (Pallas)

## Caspian Tern

Recorded by MacGillivray (1846), and listed as a breeding species by Serventy *et al.* (1971, 209).

*Sterna bergii* Lichtenstein

## Crested Tern

This species was not mentioned by either Jukes or MacGillivray in 1843-44. It may be the species described by Gould (1848, VII, 23) as

*Thalasseus pelecanoides*, the Torres Straits Tern, on which he quotes MacGillivray's observation of "three small parties upon a low ridge on one side of the island", noting that it bred in June.

Otherwise the first record is that by M'Lennan on 9 July 1911, when he observed a small colony in the centre of the island (Macgillivray 1914, 141). Macgillivray himself found two small colonies in the centre in December 1913. "The birds themselves were very numerous ... they were frequently seen in the early morning carrying off turtles' eggs from the sandy shore when these had been unearthed by the nesting reptiles" (Macgillivray 1917, 84). A few were seen by Warham (1961, 87) in February 1959, but were not breeding; and none were seen by Hindwood et al. (1963, 38) in November 1961.

Lavery and Jones (1971) map large colonies of this species on Michaelmas and Upolu Cays, near Cairns, and on the Barnard Islands; Serventy et al. (1971, 219) record colonies in the Bunker and Capricorn Groups.

*Sterna fuscata nubilosa* Sparrman

Sooty Tern

The first record at Raine is that by Jukes in July 1843, when he found young of all ages (Jukes 1847, I, 129). In May 1844 MacGillivray (1846, 1476-77), under the name *Thalassipora fuliginosa*, found it breeding in large colonies, on the ground, and said that many eggs were taken. Gould (1848, VII, 33) refers to it as *Onychoprion panaya*. Moseley in August 1874 found it breeding in grass around the shore; Tizard et al. (1885) describe it as "exceedingly abundant" on "flat ground above the shoreline covered with grass". "The stretches of flat ground above the shore were absolutely full of the brown fledged young of this bird. Eggs were already very scarce" (Moseley 1879, 301). Saunders (1878) records *Challenger* material.

Macgillivray (1910) recorded Sooty Terns in October 1910, and in July 1911 M'Lennan found them (reported as *Onychoprion fuliginosa*) "nesting in tens of thousands all over the island" (Macgillivray 1914, 142). In December 1913, Macgillivray (1917, 85) found them coming in from the sea at about 5 p.m. "in immense numbers", circling without landing, then leaving again at dawn, presumably as a preliminary to breeding. Sooty Terns are also recorded for Raine by Alexander (1925).

In February 1959 Warham (1961, 87-88) found "vast numbers" on the dunes, especially in the south. The birds were never seen on the ground in 1959, though their numbers increased at night. Warham stated that this species breeds between April and November, and is present but does not alight between December and March. Hindwood et al. (1963, 38) found it present in November 1961. In November 1973 Sooty Terns were abundant on the ground in *Lepturus* grassland on the high ridge, especially towards the west end, during the hours of darkness, but they were absent during the day.

According to Lavery and Grimes (1971) and Serventy *et al.* (1971, 227), Raine Island is the major breeding site of Sooty Terns on the Great Barrier Reef, though there are several other large colonies north of Michaelmas Cay, a distribution very similar to that of the Noddy *Anous stolidus*.

*Sterna anaethetus anaethetus* Scopoli

Bridled Tern

Reported by Macgillivray (1910) and Macgillivray (1917, 85), who recorded this species (as *Onychoprion anaetheta*) nesting in "great numbers" in crevices and on piles of rock in the centre of the island in December 1913. Warham (1961, 88) found very few in February 1959 and thought they had already left the island. They are said to breed under the cliffs. Lavery and Grimes (1971) state that Raine is the major breeding site for this species on the Great Barrier Reef, but there are many lesser sites along the Reef (Serventy *et al.* 1971, 229).

*Anous stolidus pileatus* (Scopoli)

Noddy

Jukes (1847, I, 129) found young of all ages in July 1843. In May 1844 MacGillivray (1846, 1476-77) reported "myriads", building nests of small twigs and coral fragments. In August 1874 Moseley (1879, 300) found them breeding in grass around the shore, building "a rude nest of twigs and grasses amongst the low bushes, but often also ... on the ground. There were plenty of eggs of this bird"; specimens were taken (Saunders 1878).

In October 1910 Macgillivray (1910, 226) found "noddies ... in great numbers, but ... not yet commenced to nest". In July 1911 they were "nesting all over Raine Island" (M'Lennan in Macgillivray 1914, 142). In December 1913 they were "in great numbers, lining the seashore of the island or in small colonies all over the island, mostly composed of fully-fledged young and their parents. Many more were continually over the sea ... and towards nightfall many more came in to roost on the island" (Macgillivray 1917, 85).

Warham estimated the population at 2000 in February 1959. Birds were present during the day, congregating on the northern beach during the afternoon, and many coming in from the sea at dusk. There were dense flocks on the central flats during the night. Warham thought they were collecting prior to nesting (Warham 1961, 88). Hindwood *et al.* (1963, 38) found them present in November 1961, and Ogilvie (1975) found some 400 birds.

Lavery and Grimes (1971) and Serventy *et al.* (1971, 232-233) cite Raine Island as a major breeding site for this species, together with several other islands on the northern Great Barrier Reef; this distribution is similar to that of the Sooty Tern.

*Anous minutus minutus* Boie

## White-capped Noddy

This species is recorded as *Anous leucocapillus*, White-capped Tern, by Gould (1848, VII, 36), who quotes Lt Ince's observation that it is "very abundant" at Raine Island; this observation probably refers to the Common Noddy. There is no further record of this species at Raine until Warham's visit in February 1959. He (1961, 88) found two or three, and since this species nests in trees, he did not believe it bred on Raine. Hindwood *et al.* (1963, 38, 42) collected a male in November 1961 (Western Australian Museum No. A8768).

All the large colonies of this species on the Great Barrier Reef are in the Bunker and Capricorn Islands in the far south (Lavery and Grimes 1971; Serventy *et al.* 1971, 235-237). Its status on Raine Island remains uncertain.

*Larus novaehollandiae forsteri* (Mathews)

## Silver Gull

This may be the species recorded as *Xema Jamesonii* in 1844 by MacGillivray (1846, 1477), who noted "only a few pairs". Moseley (1879, 300) collected it in August 1874 (Saunders 1878), but said it did not breed. In December 1913 Macgillivray (1917, 86) found it "in fair numbers ... constantly to be seen early in the morning on the sandy strip above high tide mark on the look-out for turtle eggs that had been scooped out by these creatures during the night". In February 1959 Warham (1961, 88) found small numbers and no nests, and noted that there was no breeding record from Raine; he estimated the population to be 25. Hindwood *et al.* (1963, 38; Hindwood 1964, 310) found "a few birds", and Ogilvie (1975) 3-4. This species is very widely distributed along the Great Barrier Reef (Lavery and Grimes 1971; Serventy *et al.* 1971, 196), but is unimportant at Raine Island.

*Arenaria interpres interpres* (Linnaeus)

## Turnstone

This species was recorded from Raine Island in 1844 as *Strepsilas australis* by MacGillivray (1846) and as *Strepsilas interpres* by Gould (1848, VI, 39). Moseley (1879, 300) found flocks on the shore in August 1874, but no nests; one male and two females were taken and reported as *S. interpres* by Forbes (1878). Macgillivray (1971, 86) found several small flocks on the shore in December 1913. Warham (1961, 88) found small flocks everywhere except in the vegetated areas in February 1959. It was noted as present by Hindwood *et al.* (1963, 38) in November 1961.

*Pluvialis squatarola* (Linnaeus)

## Grey Plover

The only record is that of a female collected by Macgillivray on 10 December 1913 and reported as *Squatarola helvetica* (Macgillivray 1917, 86).

*Pluvialis dominica fulva* (Gmelin) Eastern Golden Plover

This species was "many times noted in all parts of Raine Island" by Macgillivray (1914, 86) in December 1913. Warham (1961, 88) found 20 present on the beach, dunes and central flat in February 1959. Hindwood et al. (1963, 38) report it not present in November 1961, but in the same paper record a specimen collected there (Hindwood et al. 1963, 42), a male now in the Western Australian Museum (No. A.8754).

*Numenius phaeopus variegatus* (Scopoli) Whimbrel

The only record is of a single bird seen by Warham (1961, 89) in February 1959. It was not seen by Hindwood et al. (1963, 38) in November 1961.

*Limosa lapponica baueri* Naumann Bar-tailed Godwit

The only record is a sighting by Hindwood et al. (1963, 32) on 11 November 1961.

*Calidris canutus* (Linnaeus) Lesser Knot

Amiet (1957, 252) mentions an earlier sighting of this species "in the vicinity of Raine Island". Kikkawa (1976, 319) lists the species for Raine from this record.

*Calidris ruficollis* (Pallas) Red-necked Stint

This is probably the species recorded from Raine as *Schoeniclus albescens* by Gould (1848, VI, 31) and as *Actodromas australis* in Gould (1865, II, 257) (for synonymy see Sharpe 1896, 545). Four were seen feeding along the shore by Hindwood et al. (1963) in November 1961, and reported as *Erolia ruficollis*. One male and one female were collected and are in the C.S.I.R.O. collection (Nos. 302, 303).

*Calidris acuminatus* (Horsfield) Sharp-tailed Sandpiper

Macgillivray (1917, 87) (under *Pisobia acuminata*) found it "common" in December 1913. It was not present during Warham's visit in February 1959 (Warham 1961, 89).

*Egretta alba modesta* (Gray) White Egret

Warham (1961, 89) saw one bird on the south ridge on 13 February 1959.

*Egretta sacra* (Gmelin) Reef Heron

This was recorded as "*Erodias*, two species" by J. MacGillivray (1846, 1477) in 1844. Both phases were present: "Some white and blue herons frequented the reef, and probably are permanent residents, judging from some deserted nests and fragments of eggs which I saw". Gould (1848, VI, 60) cites it as *Herodias jugularis* Blue Reef Heron,

and notes that it "breeds among the recesses of the rocks". William Macgillivray (1914, 145) saw one bird in 1911. It was not seen by either Warham (1961, 89) in February 1959, or by Hindwood (1964, 311) in November 1961, or by ourselves in November 1973.

*Nycticorax caledonicus hilli* Mathews

Nankeen Night Heron

The first record of this distinctive species is M'Lennan's record of "many" on 15 July 1911 (Macgillivray 1914, 146); he found no nests but two young birds came into his camp. Macgillivray found one egg on 9 December 1913. Attenborough recorded one or two juveniles, unable to fly, in July 1957. By contrast Warham (1961, 80, 89) found "well over a thousand" in February 1959, with several hundred clutches of eggs on ridges, under overhangs, and on piles of rocks on the central flat; there were few eggs. Warham considered that this species occupied the niche on Raine that elsewhere was occupied by the Reef Heron. But in November 1961 Hindwood et al. (1963, 33) found only "about 50 birds" and "no signs that they were breeding". In November 1973 there was one large flock of about 150 birds, generally on the beach at the east end of the island. Ogilvie (1975) later found more than 2000 birds.

*Merops ornatus* Latham

Australian Bee-eater

First recorded as a visitor by Ellis (1937, 178), who saw "quite a number" during 1890-92. Ten were seen in two groups on 11 November 1961 by Hindwood et al. (1963, 7).

*Hirundo nigricans nigricans* Vieillot

Tree Martin

First recorded by John MacGillivray in 1844. A few birds were seen by Warham (1961, 89) in February 1959 and recorded as *Hylochelidon nigricans*. It is recorded as *Petrochelidon nigricans* (Vieillot) by Kikkawa (1976, 332).

*Monarcha melanopsis* (Vieillot)

Black-faced Flycatcher

This is cited by Macgillivray (1918) and recorded by Kikkawa (1976, 333).

*Myiagra rubecula rubecula* (Latham)

Leaden Flycatcher

According to Warham (1961) this is the species cited as *Rhipidura* by John MacGillivray in 1844. One was seen by W. Macgillivray (1918, 198) on 10 December 1913, and two the following day, all in the Beacon.

*Aplonis metallica metallica* (Temminck)

Shining Starling

One bird was seen on the Beacon by W. Macgillivray on 10 December 1913.

## DISTURBANCE BY MAN

When the *Fly* arrived at Raine there was no trace of native occupation (Jukes 1847, I, 130), and there is no reason to suppose that the island had ever been occupied before this time. During the nineteenth century, however, considerable disturbance took place, first during the building of the Beacon in 1844, most severely during the guano digging period before 1892, and to an unknown extent during visits by beche-de-mer fishermen in the 1870s and 1880s. Accessible food resources such as nesting turtles and their eggs, and ground-nesting seabirds and their eggs, must have undergone severe if spasmodic interference at these times. In addition to this direct predation, some of these visitors introduced plants, mainly vegetables which they attempted to cultivate, and on at least one occasion goats were liberated too.

During the *Fly*'s first visit, Jukes dined "upon young boobies and frigate-birds and terns' eggs - the latter were excellent, and the former very good, especially when cooked with a little curry powder" (1847, I, 129-130). In 1844 the island was occupied for four months during the building of the Beacon. Jukes estimated in June that 3000 young birds (Noddies and Sooty Terns) and about 17,000 eggs had been eaten by the shore party. Later, when a small party landed from the *Bramble* in April-May 1845, Sweatman (MS, 93) records that 36 dozen eggs a day were consumed by three men: "add to this turtle soup, eels, mutton birds (which Clark cooked magnificently) fish, spinach and damper ..." As is still the practice in egg collecting, Sweatman states that "Our first act on landing was, of course, to break every egg on the island so that all we collected afterwards were sure to be fresh, and so abundantly did the birds lay that besides supplying our own wants at the rate above stated we lined in three large casks for the use of the ship". Gardens were also established in the centre of the island by the *Fly* party, and coconuts, pumpkins, maize and other plants introduced and cultivated (Jukes 1847, II, 267).

In January 1845 (Sweatman's manuscript says February), during the *Heroine*'s visit, Mackenzie (1845, 494) planted "cocoa-nut and various other seeds, hoping they might be a benefit to some unfortunates hereafter"; four months later the coconuts were reported "growing very fast" (Anon. 1846, 549). Sweatman (MS, 91) then described them as four feet tall but choked with weeds which had already obliterated the paths and gardens. The *Bramble* party cleared the weeds from round the young trees, built fences around them, and planted four more brought from the Murray Islands (Sweatman MS, 96), but in spite of this these introductions did not long survive. When the *Challenger* called in 1874, Moseley (1879, 300) planted pumpkins, tomatoes, water melons, Cape Gooseberries, and *Capsicum*, but no later visitor mentions any of these surviving either.

Goats were introduced at an early stage, according to Lack (1953, 41) by the *Fly*, though there seems to be no contemporary evidence that this was so. In January 1845, however, the *Heroine* "left a male and female goat, with two bags of rice" (Mackenzie 1845, 494). Sweatman



(MS, 92) in April found them "frisking about the island in good condition but very wild and shy", and by August there were three young (Anon. 1846, 549). There is a mention of "numbers" of goats being present at the time of the wreck of the *Enchantress* in July 1850, but otherwise no later record. The goats were doubtless eaten during the beche-de-mer and guano digging periods, if they had not died out before, and they were themselves probably responsible for the disappearance of the *Fly's* vegetable gardens.

Early visitors continued to obtain food supplies from the seabirds and turtles. The *Heroine* in 1845 "obtained fourteen large turtles ... also an immense number of eggs, and the crew killed birds out of number" (Mackenzie 1845, 494). The *Bramble* party also took fourteen turtle by turning them on the beaches (Sweatman MS, 94-95). Buchanan (1874, 127-128) records that the *Challenger* only left "after a sufficient number of birds had been killed". Similar incidents, though not recorded in the nautical or scientific literature, must have been numerous throughout the nineteenth century.

#### Construction of the Beacon

A series of shipwrecks on the Great Barrier Reef near Great Detached Reef (including those of the *Charles Eaton* in 1834, the *Ferguson* in 1840, and the *Martha Ridgway* in 1841) led to a proposal by Capt Blackwood<sup>1</sup> that a Beacon be erected on Raine Island to guide ships using the Outer Passage route through the Barrier Reef. The Beacon was originally to be triangular in plan and 60 ft high, but as announced by Blackwood (1844b) it was proposed to build a tower 50 ft high, 25 ft in diameter at the base, and 16 ft in diameter at the top, and to make it more conspicuous by painting it with black and white bands each one third the height of the building.

Blackwood fitted out for this expedition in Sydney, obtaining "twenty picked convicts, chiefly masons and quarry men", and taking on stores and prefabricated wooden huts. The captain had to spend £180.14.5d on mason's tools since both the Government and the Engineers Department refused to supply them. The *Fly*, with the *Bramble* and the *Prince George*, sailed on 27 March 1844, and commenced landing on Raine on 27 May. Jukes wrote to his sister Amelia on 26 May: "Our lumber consists of twenty convicts, and an immense quantity of plank timber, houses, barrows, jumpers, pickaxes, spades, and all manner of building, digging, and blasting materials. All these will have to be carried in boats through a heavy sea six miles, as the ship cannot anchor nearer

---

1. This account is based on the Captain's letters from H.M.S. *Fly*, Blackwood's *Remark Books*, and the engineering drawings, ink sketches and watercolour drawings in *Sketches and views*, vol. 6B, in the archives of the Hydrographic Department, Royal Navy, as well as on published accounts. We are grateful to the Hydrographer, Admiral D.W. Haslam, for access to the records.

Raine's Islet than that. I expect this will take us two or three weeks, as twenty of our crew are to be landed, and provisions and water for forty men for three months are no trifling matter. The bread alone will be 2500 lbs" (Jukes 1871, 224). On 29 May he wrote again, after his first landing, to report that he had "got on board just now wet through, and so tired I can hardly keep my eyes open. ... We have terribly hard, heavy, disagreeable work landing things on this little desolate islet, but hope finally to accomplish our object in building a beacon pretty well" (Jukes 1871, 225).

The huts and tents were erected, and a quarry was opened at the east end of the island. Jukes reported to his aunt on 21 June that "Good building stone is procured in abundance, wooden houses and tents are erected, lime is made, the foundation stone laid, and the first course of masonry nearly complete. Lieutenant Ince, with a party of forty men, occupies the island and superintends the work" (Jukes 1871, 226). Lime was made on the island by burning *Tridacna* and *Hippopus* shells. Water, however, had to be brought from Sir Charles Hardy's Islands, and timbers were obtained from the wreck of the *Martha Ridgway* 40 km to the south. After his first period of investigations on Raine, Jukes found the routine tedious: he told Amelia that "This period of inaction is becoming most oppressive to me. I would welcome any danger or any hardship even that would break the monotony. I am accordingly as dull, heavy, stupid, and spiritless as it is possible" (Jukes, 1871, 231).

But the shore party under Ince had the Beacon finished by mid-September. It had been designed by the *Fly's* carpenter, Stephen Moore, — 'without any exception the best Ship's Carpenter I ever met', Blackwood called him — and was described by Jukes as a circular tower of stone, 40 ft high, 30 ft in diameter at the base, and with walls 5 ft thick, "divided into three stories, each of which was partially floored, and made accessible by a ladder. It was roofed at the top by a dome-shaped frame of wood, covered by painted canvas. Its summit was thus raised 70 feet above low water mark. A large tank taken from the *Martha Ridgway* was placed at the side, into which a series of spouts were led from the roof, so that it would shortly be filled with rainwater" (Jukes 1847, I, 267). The drawings for the Beacon, in the Royal Navy's Hydrographic Department archives (Figure 10), indicate that the foundation stone was 11 ft above low water mark, the height to the top of the stone balustrade was 45 ft and to the top of the canopy 63 ft 2 inches, giving an elevation overall from low water mark of 74 ft 2 inches. It was painted in black and white vertical stripes and was visible from thirteen miles. Blackwood formally reported on the work by letter to the Admiralty from Surabaya on 26 October 1844.

Four months after it was completed, the Beacon was inspected by the *Heroine*: "At daylight we went on shore to examine the beacon, when we likewise found two wooden built houses and an oven. The beacon is sixty feet in diameter, and about fifty feet high, and its walls at the base three feet in thickness, painted red on the south-east side, and the rest black, with a white cupola and black ball,

having a spout which runs off it into a deep tank, which we found full of water. Altogether it is a substantial building, and well contrived throughout" (Mackenzie 1845, 494). Later the same year the same ship "sent a boat ashore to leave a letter in the Post-Office" (since Raine at this time, as Sweatman (MS, 96) also tells, performed the same kind of function as the better known Booby Island in Torres Straits at a later date), and found that "the tank was full of water, and the beacon seemed to stand the weather very well" (Anon. 1846, 549). The Beacon itself was visible from 8-9 miles from the deck of a ship and from 12-13 miles from the masthead (Horsburgh 1855, 883-884; Horsburgh 1852, I, 798-800; Findlay 1884, 971).

When examined by Capt Denham in 1860 the dome had fallen, reducing the height to 40 ft (Findlay 1884, 971), and the beams and floors had gone and the iron tank disintegrated by the time of the *Challenger's* visit in 1874 (Tizard et al. 1885; Swire 1938, II, 47-50). The ship's plumber was sent ashore to cut the Captain's name and that of the ship in the stone inside the tower (Swire 1938, II, 50), the whole surface now being covered by overlapping inscriptions by casual visitors.

In 1959 Warham found that part of the base of the tower was starting to collapse (Warham 1963, 5, photograph), but this damage was repaired with bags of cement by H.M.A.S. *Gascoyne* in 1961. The Beacon is of some historical importance, since it is the oldest stone structure built by Europeans in North Queensland.

#### Wreck of the Enchantress

Lack (1953, 41) writes: "Five years later [after the Beacon was built], Captain Anson of the brig *Enchantress*, Sydney to Sourabaya, managed to put his ship ashore on the northern side of the Raine Entrance despite the warning of the tower. A young passenger named Buchan wrote a racy account of the incident to his relatives in England. He related how they landed on the island, found numbers of the much enduring goats, and quantities of sea birds' eggs on which they feasted sumptuously". The crew rapidly became drunk and were taken off by a second vessel, the *Lady Margaret*, only with difficulty.

Efforts to obtain details of this wreck and to trace the narrative account mentioned by Lack have not been altogether successful. We are indebted to Mr. H.E. Maude who has shown that the captain's name was I'Anson, not Anson, and the passenger was Mr. B. Buchanan, not Buchan. Maude notes that the *Shipping Gazette and Sydney General Trade List*, vol. 7, no. 330 (13 July 1850), p. 186, records the departure of the *Enchantress* in ballast from Sydney. The same journal, vol. 7, no. 351, p. 322, reports its loss on the Raine reef on 24 July 1850, and prints a letter from Buchanan giving the details to the owners of the ship. The wreck occurred in the afternoon, and the ship's company escaped and took shelter in the Beacon. The *Enchantress* was travelling with the *Lady Margaret*, and everyone was taken off in small boats and transferred to this ship by dusk on the following day. The details given in Lack's published account do not derive from this letter by Buchanan, and all efforts to trace the "racy account" Lack refers to

have failed. The main interest of it lies in the references to goats and to predation of seabird eggs which it evidently contains. There is also an account of the wreck in the *Sydney Morning Herald* for 3 and 4 December 1850.

#### Beche-de-mer Fishery

During the 1880s Cooktown was the centre of the Queensland beche-de-mer fishery, when holothurians were collected from shallow reef flats, dried, and exported to China (Ward 1972). This trade had been carried out at Raine Island at least since the early 1870s. Ellis (1937, 71-72) recounts that about 1873 the fishery there was carried out by two white and two or three natives (Chinese, kanakas and aboriginals). The beche-de-mer were boiled, sun-dried and smoked on the island, though in the absence of fuel this can hardly have been on a very large scale. According to Ellis the aboriginals on one occasion murdered one of the whites, one Chinese and two kanakas, before fleeing from Raine; the bodies were buried by the surviving white man near the centre of the island.

#### Phosphate mining

When phosphate was first discovered in commercial quantities on Raine Island is not known. It was first mentioned when Raine, with other islands, was included in a lease taken out in Hobart in 1862, for seven years, for the purpose of guano digging (Crowther 1939). There is no evidence that any digging under this lease took place at Raine, although the Arundel papers contain an undated newspaper cutting stating that "The *Griffin*, under the command of German Harry, cleared yesterday for Rain Island under charter to a Southern speculator, who holds the right to take guano from that locality". Most of the guano digging activity at that time was in the more accessible Bunker and Capricorn Islands.

The J.T. Arundel Company, which had been digging on the central equatorial Pacific islands during the 1880s, transferred its operations from Baker to Raine in 1890. John Arundel records in his diary that before starting work he consulted the master of the *Jennie Scott*, One-eyed Robinson, who had worked on Raine in 1879 (though on what is not known), about sources of water there and on neighbouring islands. One-eyed Robinson told Arundel of the murder of twelve men by natives on the island during the beche-de-mer fishery. Arundel went to Raine with the *Griffin* and the *Maile* in August 1890 to organise the digging. His diaries show that he was on the island from 20 August to 6 September 1890 and again from 13 February to 15 February 1891. The digging operations were conducted by Albert Ellis, who also arrived in 1890 (though Saviile-Kent (1893) suggests that extraction began as early as 1882). There was a staff of 9-10 Europeans, and one hundred Asian (mainly Chinese) labourers; Arundel, a religious man, shipped Chinese Bibles to the island for their use.

A tramway was built from the workings to a new jetty, and a "locomotive" imported. A storage shed was built to house the guano between shipments. Export was by sailing ships of 1000-1500 tons, direct to Europe, with the exception of two which went direct to Melbourne. The guano was packed in 60 lb sacks for ease of handling. Water supply for so large a labour force was a major problem, and a water condenser was built for this purpose. In 1892 the digging ended and the equipment was dismantled and removed (Ellis 1937, 62-73, 98). It is estimated that "tens of thousands of tons" of guano were exported during this brief period (Hutchinson 1950, 256).

Sir Albert Ellis's mother died on Raine Island during this period, and is buried in a substantial grave with a marble stone adjacent to the Beacon. The inscription on the stone ends with a homily which seems especially appropriate in so remote a location:

In loving memory  
of  
Annie Eliza  
wife of  
George C. Ellis  
entered into rest  
June 29th. 1891  
aged 52 years  
Her last words were  
Father! not my will  
But thine be done.  
My - God - of - Love

Reader!

Be ye also ready

#### ACKNOWLEDGEMENTS

This report results from a visit to Raine Island made during Phase III of the Royal Society and Universities of Queensland Expedition to the Great Barrier Reef in 1973. We thank the sponsors of the expedition, and especially James Cook University of North Queensland, which made its research vessel *James Kirby* available for this visit.

We are particularly grateful to C.W. Benson, Department of Zoology, Cambridge University, for advice and comments on the birds of Raine Island and for re-examining Raine Island specimens in the British Museum (Natural History) and in the University Museum of Zoology, Cambridge; and to C.J.O. Harrison, S.A. Parker, and H.J. Lavery for other comments on birds. We are grateful to Dr J. Kikkawa for making available unpublished material on his surveys of birds on the Great Barrier Reef, and for sending data collected by P. Ogilvie (1975), which Mr. Ogilvie has allowed to be included. Dr M.R. Clarke and Dr A. Wheeler determined squid and fish respectively from seabird regurgitate. For determinations of Crustacea we thank Dr R.W. Ingle, British Museum (Natural History). Mr E.I. Butler, Marine Biological Association, Plymouth, kindly carried out phosphate analyses of soil samples.

Professor H.E. Maude of Canberra helped greatly with the enquiry about the *Enchantress*, and Dr Harold Fox pursued various lines of enquiry in Cambridge and London. Dr J. Allen of Canberra kindly made available the relevant portion of Sweatman's journal, through Dr Roger McLean, and has allowed quotations to appear here. Mr R.A. Langdon of the Pacific Manuscripts Bureau, Canberra, made available copies of the Raine Island sections of J.T. Arundel's journals. Admiral Haslam allowed access to papers of the *Fly* survey in Hydrographic Department archives. Dr S. Everist, Director, The Queensland Herbarium, Brisbane, arranged for Miss S. Reynolds to identify the plants collected in 1973, and this material was also examined by Dr F.R. Fosberg. Dr T.P. Scoffin, Grant Institute of Geology, Edinburgh University, examined rock samples.

Mr M. Young and Mr R. Coe of the Department of Geography, Cambridge University, prepared the maps and the photographs respectively.

#### REFERENCES

- Agassiz, A. 1898. A visit to the Great Barrier Reef of Australia in the steamer "Croydon", during April and May, 1896. *Bull. Mus. comp. Zool. Harvard Coll.* 28(4): 95-148.
- Alexander, W.B. 1925. Sea-birds of the Great Barrier Reef. *Rept. Gt. Barr. Reef Comm.* 1: 47-51.
- Amiet, L. 1957. A wader survey of some Queensland coastal localities. *Emu*, 57: 236-254.
- Anon. 1845. Torres Strait: Beacon on the Great Barrier Reef. *Naut. Mag.* 14: 267-268.
- Anon. 1846. Nautical notices. The pass through Torres Straits: Passage of the Heroine through Torres Straits. *Naut. Mag.* 15: 548-551.
- Anon. 1973. The exploits of the 'Cecil Rhodes of the Pacific'. *Pambu*, 33: 1-6.
- Arundel, J.T. MS. *Diary*. Pacific Manuscripts Bureau, Canberra.
- Ashmole, N.P. and Ashmole, M.J. 1967. Comparative feeding ecology of sea birds of a tropical oceanic island. *Bull. Peabody Mus. nat. Hist. Yale Univ.* 24: 1-131.
- Bateson, C. 1972. *Australian shipwrecks: including vessels wrecked en route to or from Australia, and some strandings. Vol. 1: 1622-1850.* Sydney: A.H. and A.W. Reed. 268 pp.
- Bennett, I. 1971. *The Great Barrier Reef.* Melbourne: Lansdowne Press. 183 pp.

- Birtles, A. 1978. Discussion. *Gt Barr. Reef Mar. Park Auth. Workshop Series*, 1: 368.
- Boulenger, G.A. 1889. *Catalogue of the Chelonians, Rhynchocephalians and Crocodiles in the British Museum (Natural History)*. London: Trustees of the British Museum (Natural History). 311 pp.
- Blackwood, F.P. 1844a. Nautical notices. Outer Passage to Torres Strait. *Naut. Mag.* 13: 184.
- Blackwood, F.P. 1844b. Torres Strait: Beacon on Raine Island, New South Wales. *Naut. Mag.* 13: 527.
- Blackwood, F.P. 1844c. The Barrier Reef, near Raine Island, from lat. 13°30'0"S. to 9°55'0"S. *Naut. Mag.* 13: 537-541.
- Bustard, R. 1972. *Sea turtles: natural history and conservation*. London: Collins. 220 pp.
- Bustard, H.R. and Tognetti, K.P. 1969. Green sea turtles: a discrete simulation of density-dependent population regulation. *Science*, N.Y. 163: 939-941.
- Campbell, A.J. 1901. *Nests and eggs of Australian birds*. Sheffield. Vol. 1, 524 pp., Vol. 2, pp. 525-1102.
- Campbell, Lord George. 1876. *Log letters from "The Challenger"*. London: Macmillan and Co. 448 pp.
- Clarke, M.R. 1965. Large light organs on the dorsal surfaces of the squids *Ommastrephes pteropus*, *Symplectoteuthis oulianus* and *Dosidicus gigas*. *Proc. malac. Soc. Lond.* 36: 319.
- Crowther, W.E.L.H. 1939. The development of the guano trade from Hobart Town in the fifties and sixties. *Pap. Proc. R. Soc. Tasmania* 1938: 213-220.
- Department of Harbours and Marine, Queensland. 1973. *Tide tables and notes on boating for the coast of Queensland*. Brisbane: Department of Harbours and Marine. 72 pp.
- Ellis, A.F. 1937. *Adventuring in coral seas*. Sydney: Angus and Robertson. 2nd edition, 264 pp. (1st edition not seen, 1936).
- Fairbridge, R.W. 1950. Recent and Pleistocene coral reefs of Australia. *J. Geol.* 58: 330-401.
- Fairbridge, R.W. 1967. Coral reefs of the Australian region. In J.N. Jennings and J.A. Mabbutt, eds.: *Landform studies from Australia and New Guinea* (Cambridge: University Press), 386-418.

- Findlay, A.G. 1884. *A directory for the navigation of the South Pacific Ocean; with descriptions of its coasts, islands, etc., from the Strait of Magalthishaens to Panama, and those of New Zealand, Australia, etc.; its winds, currents, and passages.* London: R.H. Laurie. 1252 pp.
- Forbes, W.A. 1878. Reports on the collections of birds made during the voyage of H.M.S. 'Challenger' — No. VII. On the birds of Cape York and the neighbouring islands (Raine, Wednesday, and Booby Islands). *Proc. zool. Soc. Lond.* 1878: 120-128.
- Frazier, J. 1971. Observations on sea turtles at Aldabra Atoll. *Phil. Trans. R. Soc. Lond.* B 260: 373-410.
- Fryer, J.C.F. 1910. Bird and Dennis Islands, Seychelles. *Trans. Linn. Soc. Lond.* (2) 14: 15-20.
- Gibbs, P.E. 1978. Macrofauna of the intertidal sand flats on low wooded islands, northern Great Barrier Reef. *Phil. Trans. R. Soc. Lond.* B 284: 81-97.
- Gould, J. 1848. *Birds of Australia.* 7 vols.
- Gould, J. 1865. *Handbook to the birds of Australia.* London. Vol. 1, 636 pp., Vol. 2, 629 pp.
- Grant, C.H.B. and Mackworth-Praed, C.W. 1933. *Sula nicolli*, sp. nov. White-tailed Red-footed Booby. *Bull. Br. orn. Club* 1933: 118-119.
- Gross, A.O., Moulton, J.M., and Huntingdon, C.E. 1963. Notes on the Wedge-tailed Shearwater at Heron Island, Great Barrier Reef, Australia. *Atoll Res. Bull.* 99: 1-11.
- Hindwood, K.A. 1964. Birds of the Coral Sea islets. *Austr. nat. Hist.* 14: 305-311.
- Hindwood, K.A., Keith, K. and Serventy, D.L. 1963. Birds of the southwest Coral Sea. *C.S.I.R.O. Division of Wildlife Research Tech. Paper*, 3: 1-44.
- Horsburgh, J. 1852, 1855. *The India Directory, or, Directions for sailing to and from the East Indies, China, Australia, and the interjacent ports of Africa and South America: originally compiled from journals of the Honourable Company's Ships, and from observations and remarks, resulting from the experience of twenty-one years in the navigation of those seas.* London: W.H. Allen. 6th edition (1852), 2 vols., 650 and 890 pp.; 7th edition (1855), 2 vols., 681 and 978 pp.



- Hughes, G. 1974. The sea turtles of south-east Africa. 1. Status, morphology and distributions. *Durban Oceanogr. Res. Inst. Invest. Rept.* 35.
- Hull, A.F. Basset. 1925. A naturalist in north Queensland. *Aust. Zool.* 4: 9-16.
- Hutchinson, G.E. 1950. Survey of contemporary knowledge of biogeochemistry. 3. The biogeochemistry of vertebrate excretion. *Bull. Am. Mus. nat. Hist.* 96: i-xviii, 1-554.
- Jukes, J.B. 1847. *Narrative of the surveying voyage of H.M.S. Fly, commanded by Capt. F.P. Blackwood, R.N. in Torres Strait, New Guinea, and other islands of the Eastern Archipelago, during the years 1842-1846: together with an excursion into the interior of the eastern part of Java.* London: T. and W. Boone. 2 vols., 423 and 362 pp.
- Jukes, J.B. 1871. Surveying expedition to Torres Strait, Great Barrier Reef, etc. 1842-1846. In: *Letters and extracts from the addresses and occasional writings of J. Beete Jukes, M.A., F.R.S., F.G.S. ... , edited, with connecting memorial notes, by his sister [C.A. Browne]* (London: Chapman and Hall), 125-268.
- Kikkawa, J. 1976. The birds of the Great Barrier Reef. In O.A. Jones and R. Endean, eds.: *Biology and geology of coral reefs* (New York: Academic Press), 3: 279-341.
- Kowarsky, J. 1978. Observations on green turtles (*Chelonia mydas*) in north-eastern Australia during the 1975/76 nesting season. *Biol. Conserv.* 13: 51-62.
- Lack, C. 1953. Australia's loneliest island. *Walkabout*, 19(9): 38, 41.
- Lavery, H.J. and Grimes, R.J. 1971. Sea-birds of the Great Barrier Reef. *Qd. agric. J.* 97: 106-113.
- Limpus, C. 1978. Sea turtles of the northern Great Barrier Reef. *Gt Barr. Reef Mar. Park Auth. Workshop Ser.* 1: 336.
- MacGillivray, J. 1846. An account of Raine's Islet, on the N.E. coast of New Holland. *Zoologist*, 4: 1473-1481.
- Macgillivray, W. 1910. Along the Great Barrier Reef. *Emu*, 10: 216-233.
- Macgillivray, W. 1914. Notes on some North Queensland birds. *Emu*, 13: 132-186.
- Macgillivray, W. 1917-1918. Ornithologists in North Queensland. *Emu*, 17: 63-87 (1917), 145-148 (1918), 180-212 (1918).

- Mackenzie, M. 1845. Voyage of the Heroine from India to Sydney, through Torres Straits. *Naut. Mag.* 14: 491-494.
- Miers, E.J. 1886. Report on the Brachyura collected by H.M.S. Challenger during the years 1873-76. *Sci. Repts. Voy. H.M.S. Challenger, Zoology*, 17: 1-362.
- Moseley, H.N. 1879. *Notes by a naturalist: an account of observations made during the voyage round the world of H.M.S. "Challenger" in the years 1872-1876, under the command of Capt Sir G.S. Nares, R.N., K.C.B., F.R.S., and Capt F.T. Thomson, R.N.* London.
- Moulton, J.M. 1961. Some observations on the Heron Island fauna. *Atoll Res. Bull.* 82: 15-16.
- Murray, J. 1895. A summary of the scientific results. *Sci. Repts. H.M.S. Challenger, Summ. Sci. Res.* 1: i-liiii, 1-796.
- Nelson, J.B. 1970. The relationship between behaviour and ecology in the Sulidae with reference to other sea birds. *Oceanogr. mar. Biol. Ann. Rev.* 8: 501-574.
- North, A.J. 1911-1914. Nests and eggs of birds found breeding in Australia and Tasmania. *Spec. Cat. Austr. Mus. Sydney*, no. 1: vol. 3 (1911-12), 1-362; vol. 4 (1913-14), 1-472.
- Ogilvie, P. 1975. Address to the Queensland Ornithological Society on Raine Island, December 1975.
- Ogilvie-Grant, M. 1898. *Catalogue of birds in the British Museum (Natural History), Part 26.* London: Trustees of the British Museum (Natural History).
- Parsons, J.J. 1962. *The Green Turtle and man.* Gainesville: University of Florida Press. 126 pp.
- Rattray, A. 1869. Notes on the geology of the Cape Yorke Peninsula. *Q.J. geol. Soc. Lond.* 25: 297-305.
- Saunders, H. 1878. On the Laridae collected during the Expedition. *Sci. Repts. Voy. H.M.S. Challenger, Zoology*, 2(8): 133-140.
- Saville-Kent, W. 1893. *The Great Barrier Reef of Australia; its products and potentialities.* London: W.H. Allen. 387 pp.
- Sclater, P.L. and Salvin, O. 1878. Reports on the collections of birds made during the voyage of H.M.S. 'Challenger' - No. XI. On the Steganopodes and Impennes. *Proc. zool. Soc. Lond.* 1878: 650-655.

- Servan, J. 1976. Ecologie de la tortue verte à l'île Europa (Canal de Mozambique). *Terre Vie*, 30: 421-464.
- Serventy, D.L., Serventy, V. and Warham, J. 1971. *The handbook of Australian sea-birds*. Sydney: A.H. and A.W. Reed. 254 pp.
- Sharpe, R.B. 1896. *Catalogue of birds in the British Museum (Natural History), Part 24*. London: Trustees of the British Museum (Natural History).
- Spry, J.J. 1876. *The cruise of Her Majesty's Ship "Challenger". Voyages over many seas, scenes in many lands*. London: Sampson Low, Marston, Searle and Rivington. 388 pp.
- Storr, G.M. 1973. List of Queensland birds. *Spec. Publ. W. Austr. Mus.* 5: i-iii, 1-177.
- Sweatman, J. MS. *Journal of a surveying voyage to the N.E. coast of Australia and Torres Strait, in H.M. Schooner Bramble, Lieut. C.B. Yule, Commander, 1842-47*. Mitchell Library, Sydney.
- Swire, H. 1938. *The voyage of the Challenger: a personal narrative of the historic circumnavigation of the globe in the years 1872-1876 by Navigating Sub-Lieutenant Herbert Swire, R.N.* London: Golden Cockerel Press. 2 vols., 192 and 168 pp.
- Taylor, R.C. 1973. *An atlas of Pacific Islands rainfall*. Hawaii Institute of Geophysics Data Report No. 25 (HIG-73-9).
- Tizard, T.H., Moseley, H.N., Buchanan, J.Y. and Murray, J. 1885. Narrative of the cruise of H.M.S. Challenger. *Sci. Repts. Voy. H.M.S. Challenger, Narrative*, 1: 1-110.
- Ward, R.G. 1972. The Pacific *beche-de-mer* trade with special reference to Fiji. In R.G. Ward, ed: *Man in the Pacific Islands* (Oxford: Clarendon Press), 91-123.
- Warham, J. 1959. The Trinidad Petrel, *Pterodroma arminjoniana*, a new bird for Australia. *Emu*, 59: 153-158.
- Warham, J. 1961. The birds of Raine Island, Pandora Cay, and Murray Island Sandbank, North Queensland. *Emu*, 61: 77-93.
- Warham, J. 1963. On the edge of the Coral Sea. *Pacif. Discov.* 16(1): 2-9.
- Whitley, G.P. 1938. John Gould's associates. *Emu*, 38: 141-167.
- Wild, J.J. 1878. *At anchor: a narrative of experiences afloat and ashore during the voyage of H.M.S. "Challenger" from 1872 to 1876*. London: Marcus Ward and Co. 196 pp.

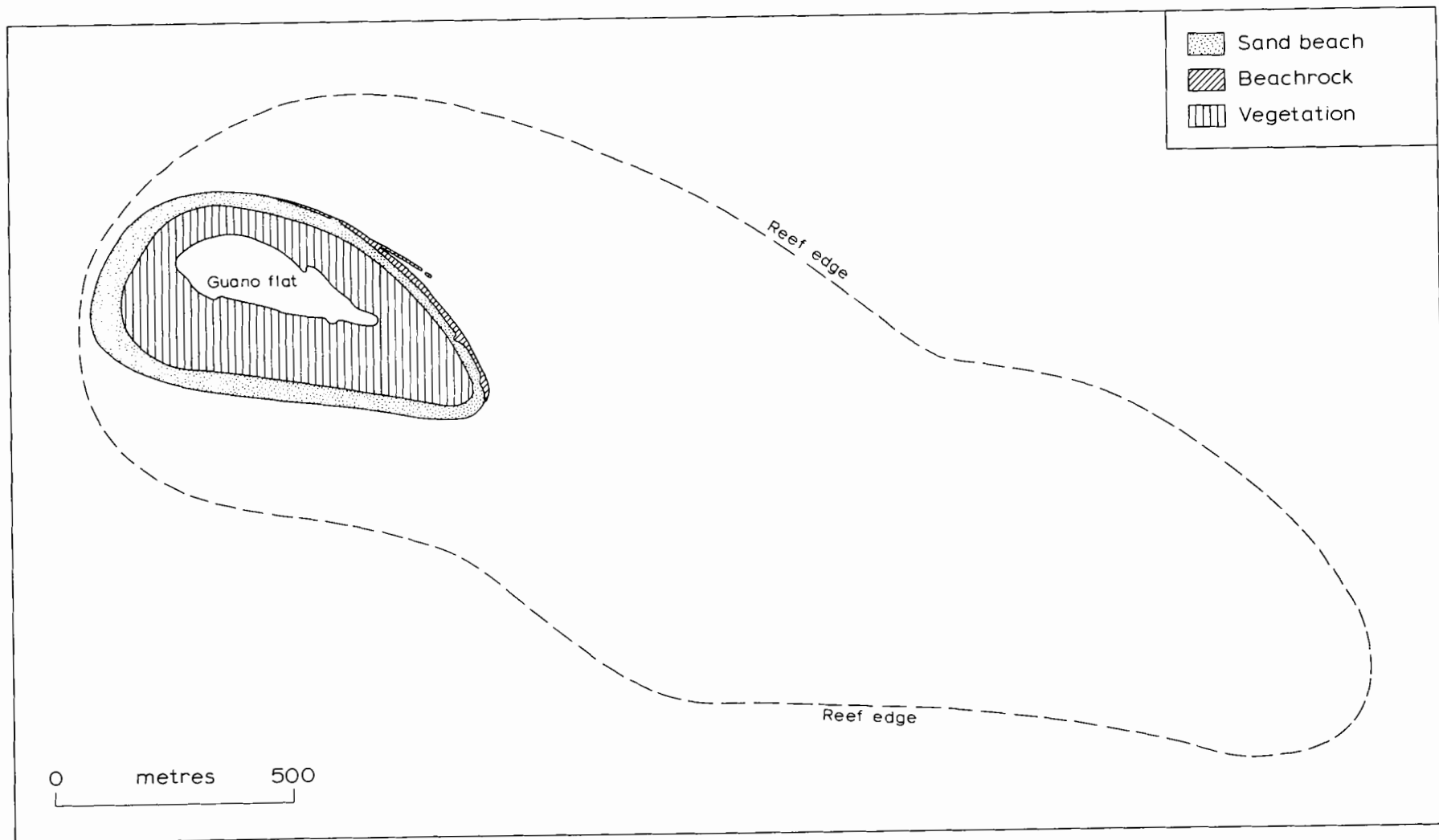


Fig. 2. Raine Island and its reef.

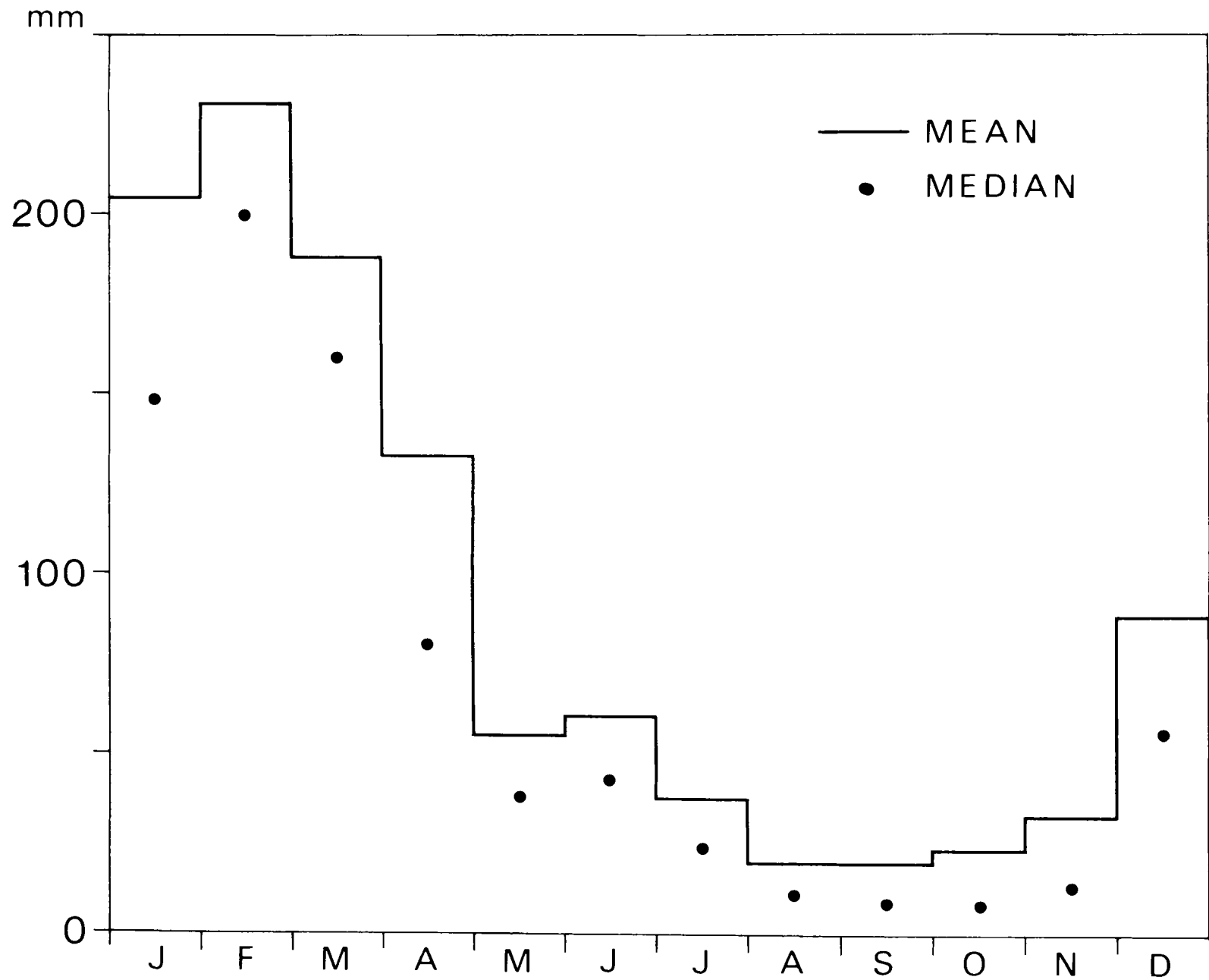
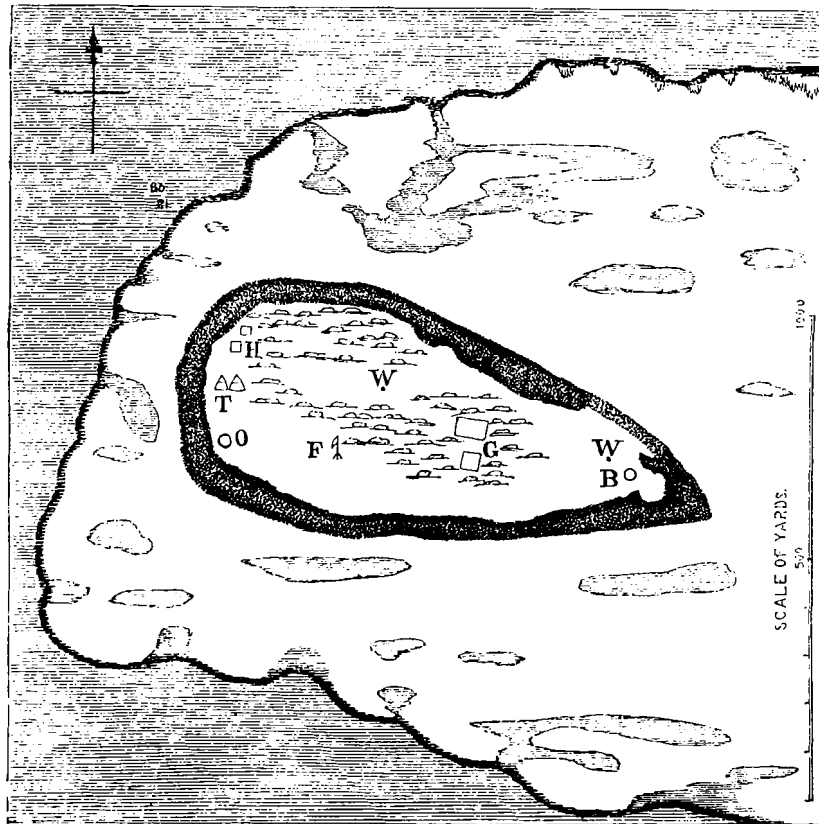
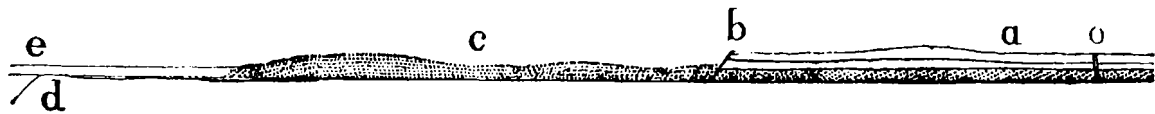


Fig. 3. Monthly distribution of rainfall at Willis Island, 1921-1971 (data from Taylor 1973).



*B.* The beacon.      *G.* The gardens.      *W.* The wells.      *F.* The flagstaff.  
*H.* The huts.      *T.* The tents.      *O.* The observatory.

Fig. 4. Raine Island in 1844, from Jukes (1847), vol. I, p. 338.



*a.* Vegetable soil.      *b.* Little cliff at edge of stone.  
*c.* Loose coral sand.      *d.* Edge of reef.  
*e.* These two lines represent high and low water level, the rise and fall being about 10 feet.

Fig. 5. Profile of Raine Island, from Jukes (1847), vol. I, p. 339.



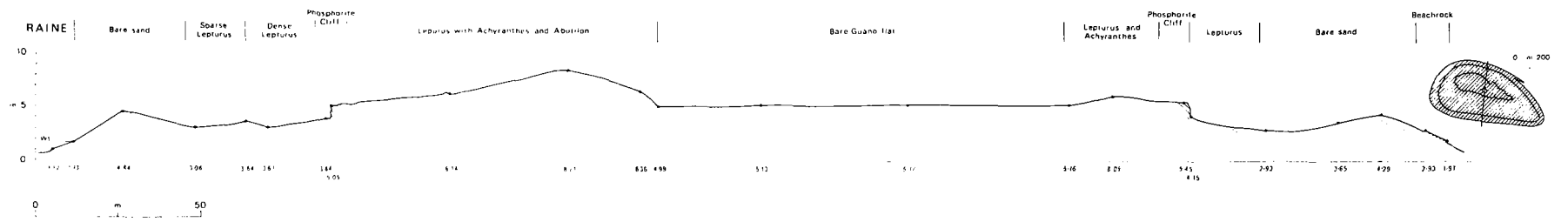


Fig. 7. Topographic profile of Raine Island.



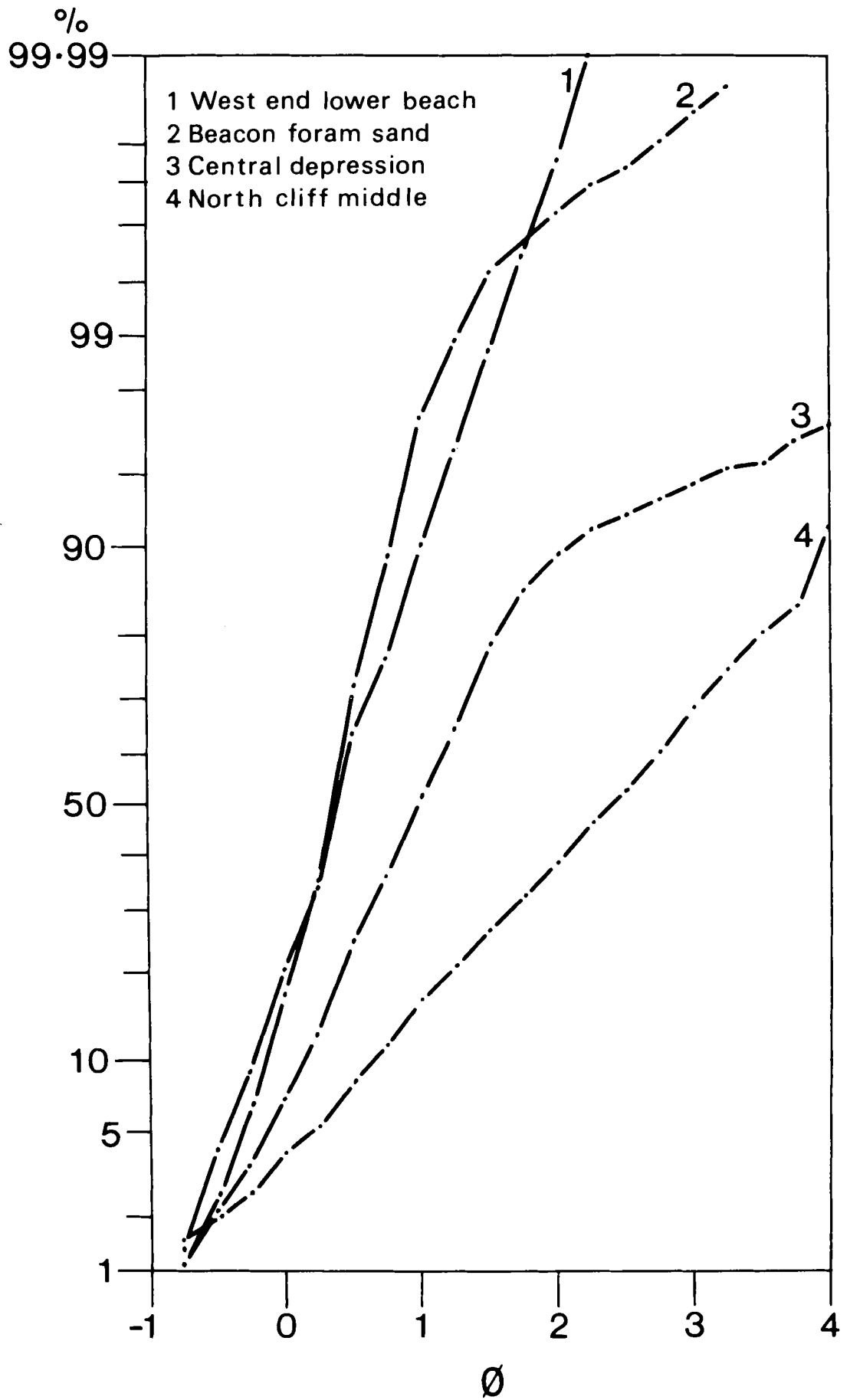


Fig. 8. Sediment samples from Raine Island.

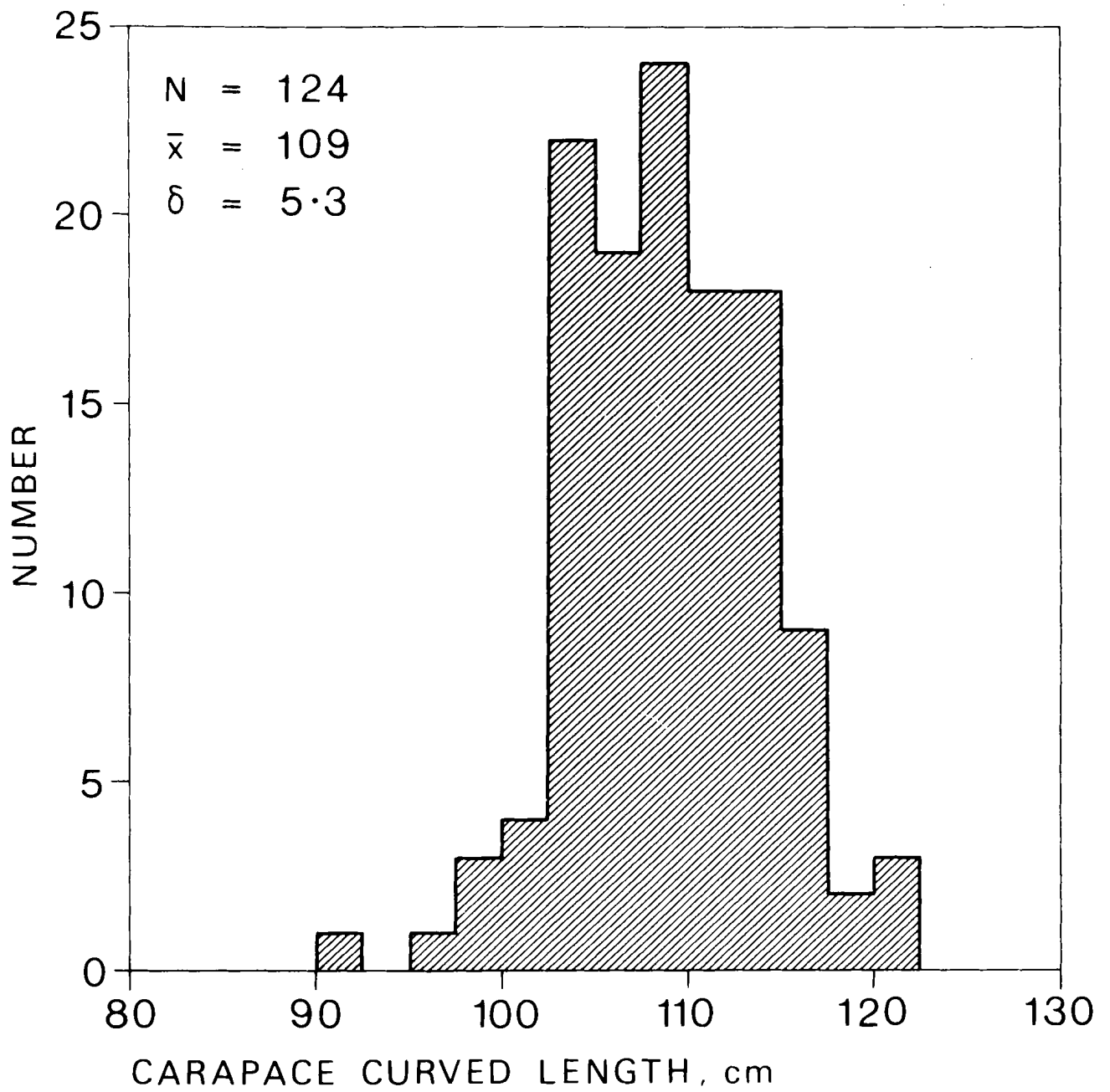


Fig. 9. Histogram of curved carapace length of turtles measured on the nest, night of 3 November 1973.

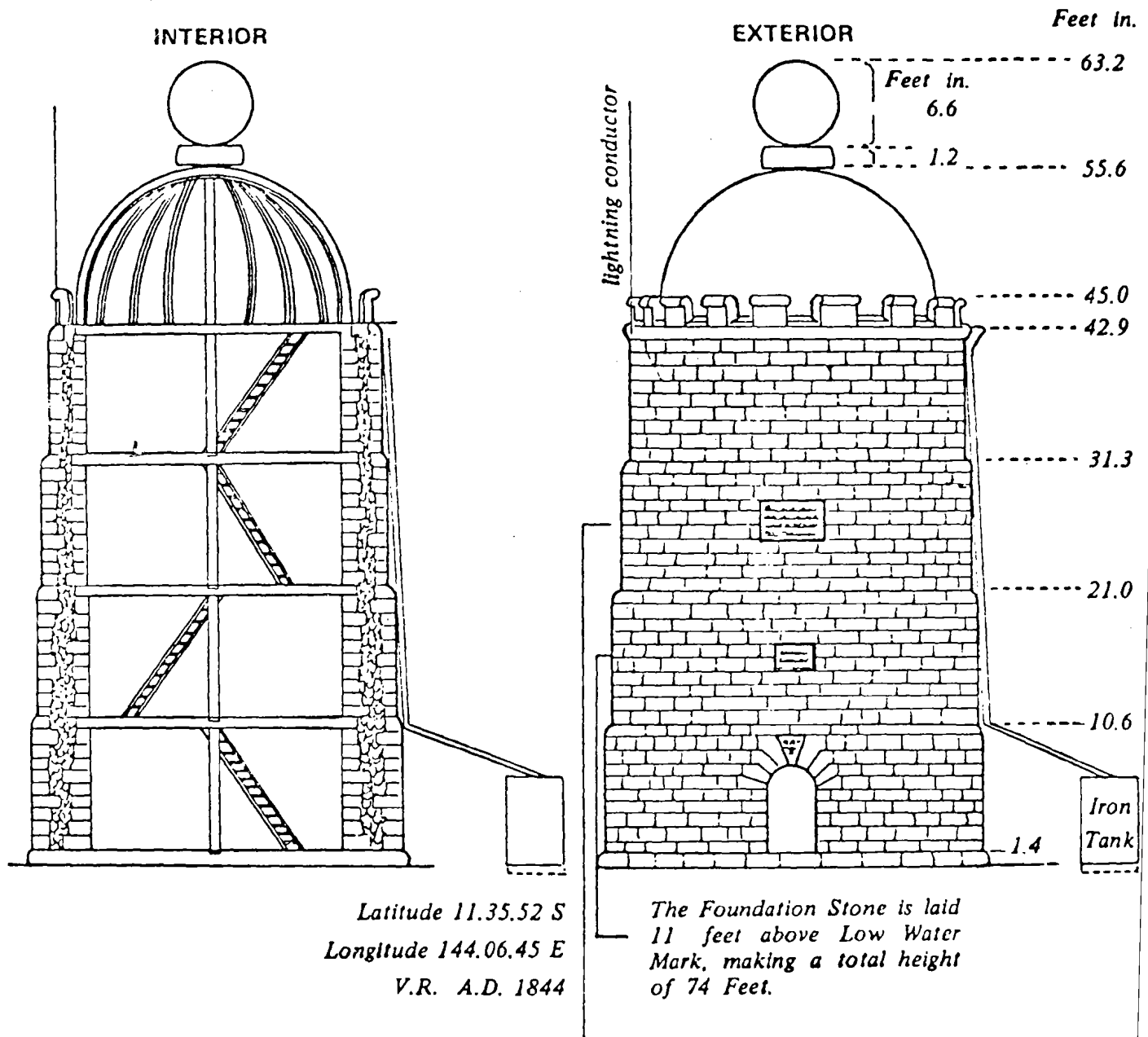
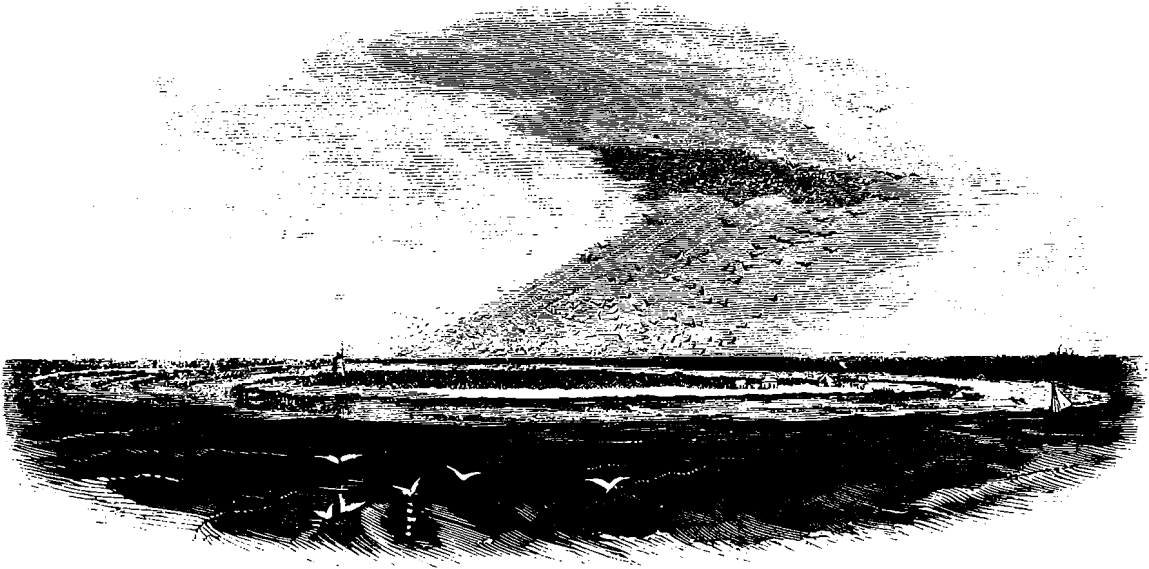


Fig. 10. Section and elevation of the Raine Island Beacon, 1844, after Bateson (1972), p. 201.

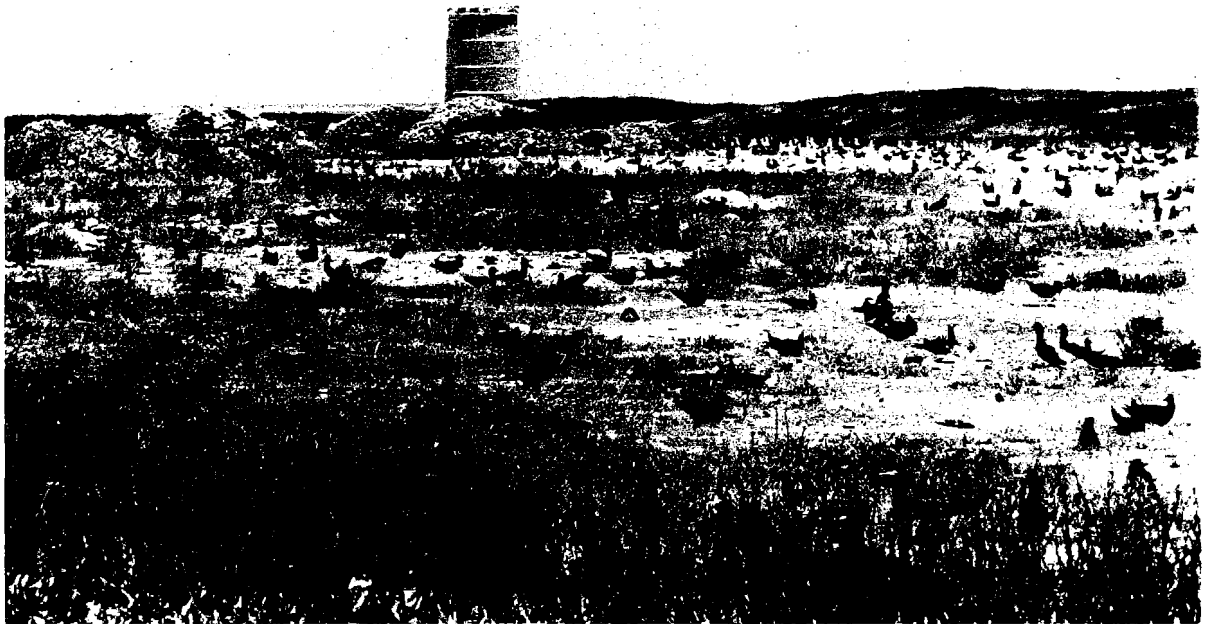


RAINE'S ISLET.

Pl. 1. Raine Island in 1844, from Jukes (1847).



Pl. 2. The central guano flat from the east end of the island, looking towards the Beacon. The ridge in the foreground is the site of the old guano railway.



Pl. 3. Eastern end of the central guano flat, with Brown and Masked Gannets.



Pl. 4. Mounds of rubble and stones in the central guano flat.



Pl. 5. Massive beachrock on the northeast shore.



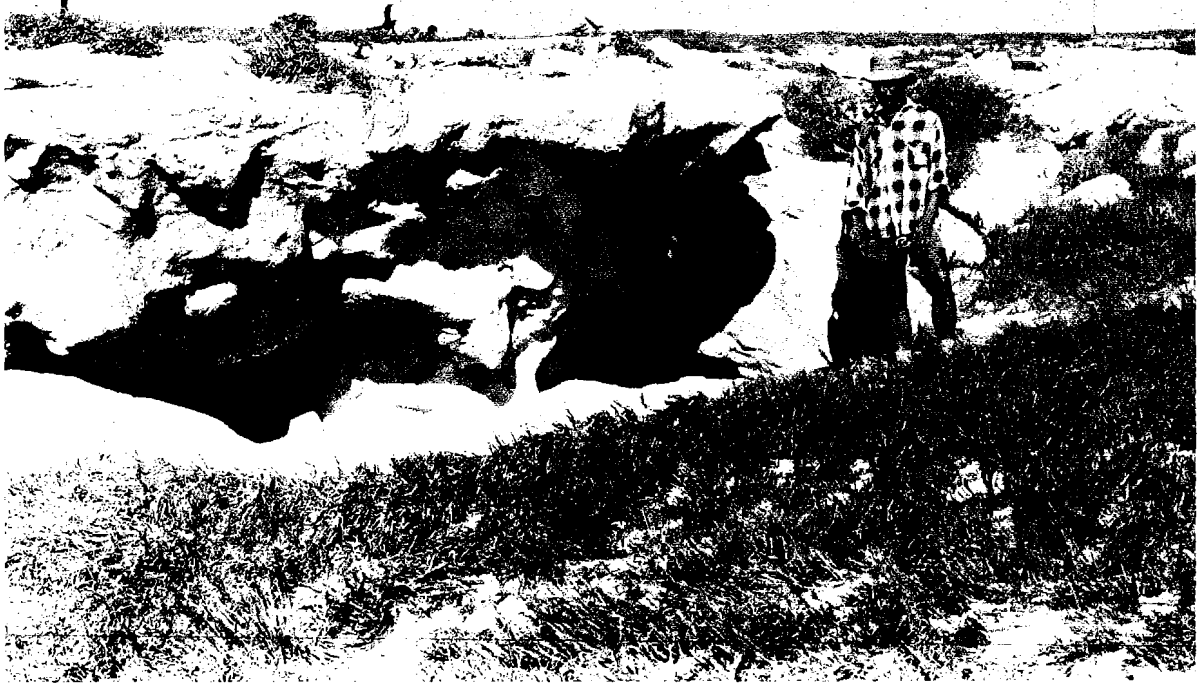
Pl. 6. Grooved and furrowed beachrock on the northeast shore.



Pl. 7. Beachrock now distant from the beach on the north shore.



Pl. 8. Phosphatic beachrock unconformably overlying old eroded beachrock at the east end of the island.

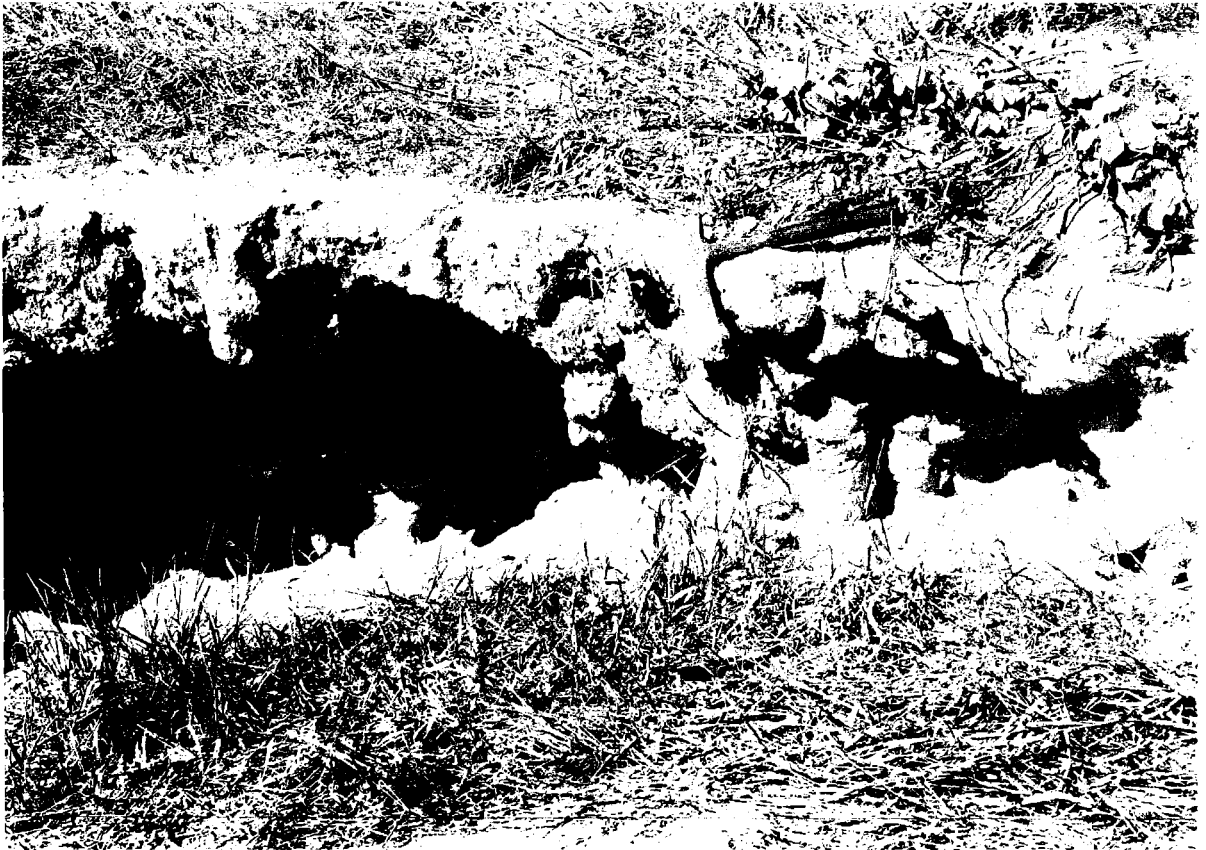


Pl. 9. Cliffs in phosphate rock at the southeast end of the island.

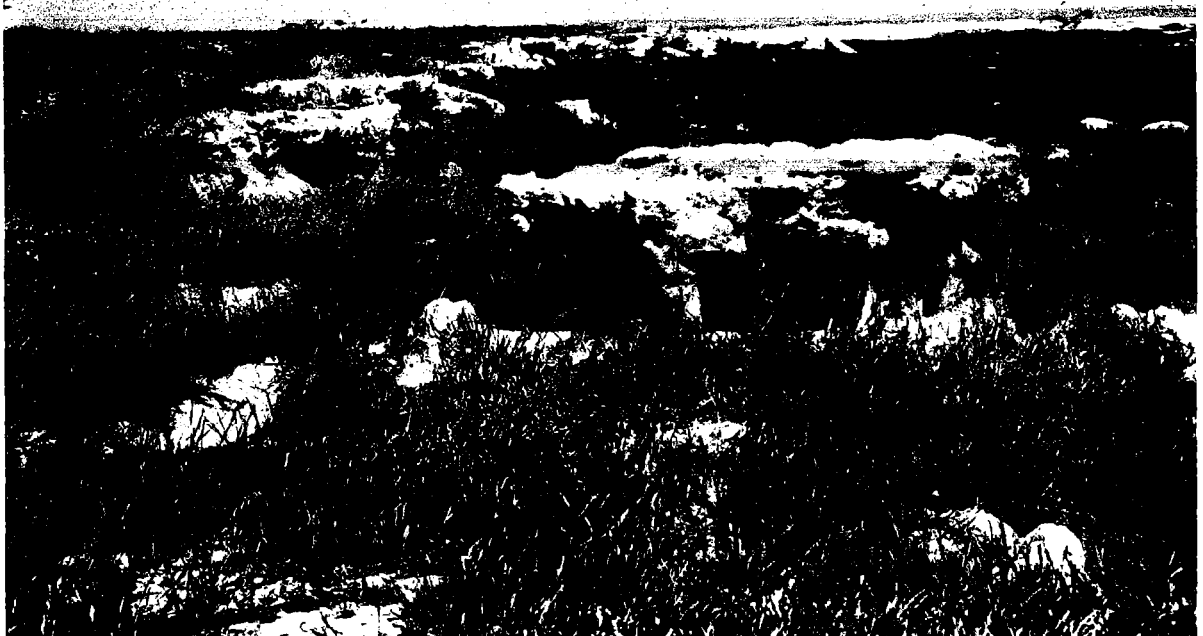


Pl. 10. Irregular lower surface of the phosphate rock, forming caves, on the south side of the island. Note the nesting Tropicbird beneath the overhang.





Pl. 11. Detail of the columnar structure of the phosphate rock.



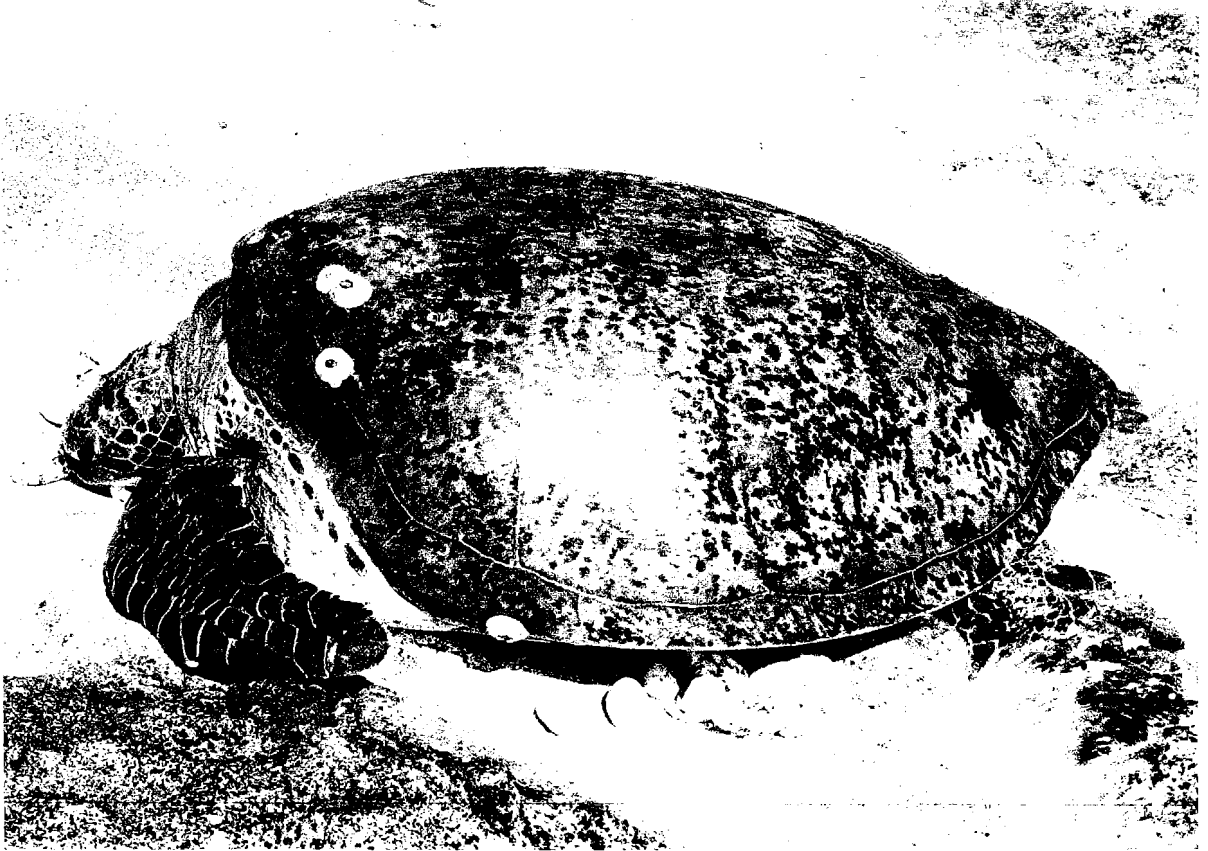
Pl. 12. Detached remnants of phosphate rock, south side of the island.



Pl. 13. Western sand beach, showing early morning turtle tracks.



Pl. 14. Turtle nests on the beach crest at the west end of the island



Pl. 15. Green Turtle on the northeast beachrock.



Pl. 16. Turtle remains in *Lepturus* grassland of the high ridge.



Pl. 17. Shearwater burrows in fine guano at the west end of the central guano flat.



Pl. 18. Mound in the central guano flat with juvenile Lesser Frigatebirds.



Pl. 19-20. Juvenile Lesser Frigate-birds.





Pl. 21. Juvenile Lesser Frigate-birds.



Pl. 22. Brown Gannets lining the beachrock at the east end of the island.

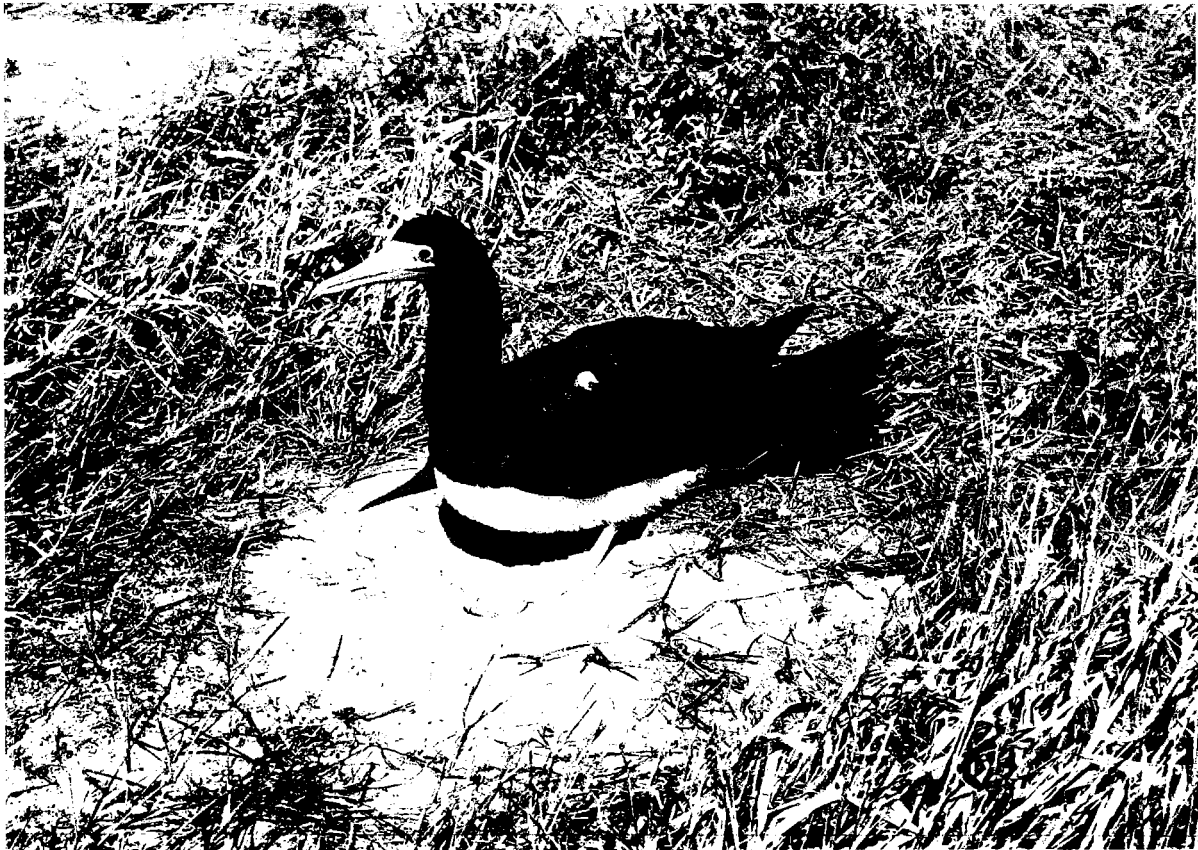


Pl. 23. Brown Gannets on beachrock on the northeast shore.



Pl. 24. Brown Gannets on the nest in the central guano area.  
Note the twigs outling the nest.





Pl. 25. Brown Gannets nesting in the *Lepturus* grassland of the high ridge. No twigs surround the nest in the vegetated areas.



Pl. 26. Masked Gannets on the nest in the central guano area. The nest is simply a depression in the sand.





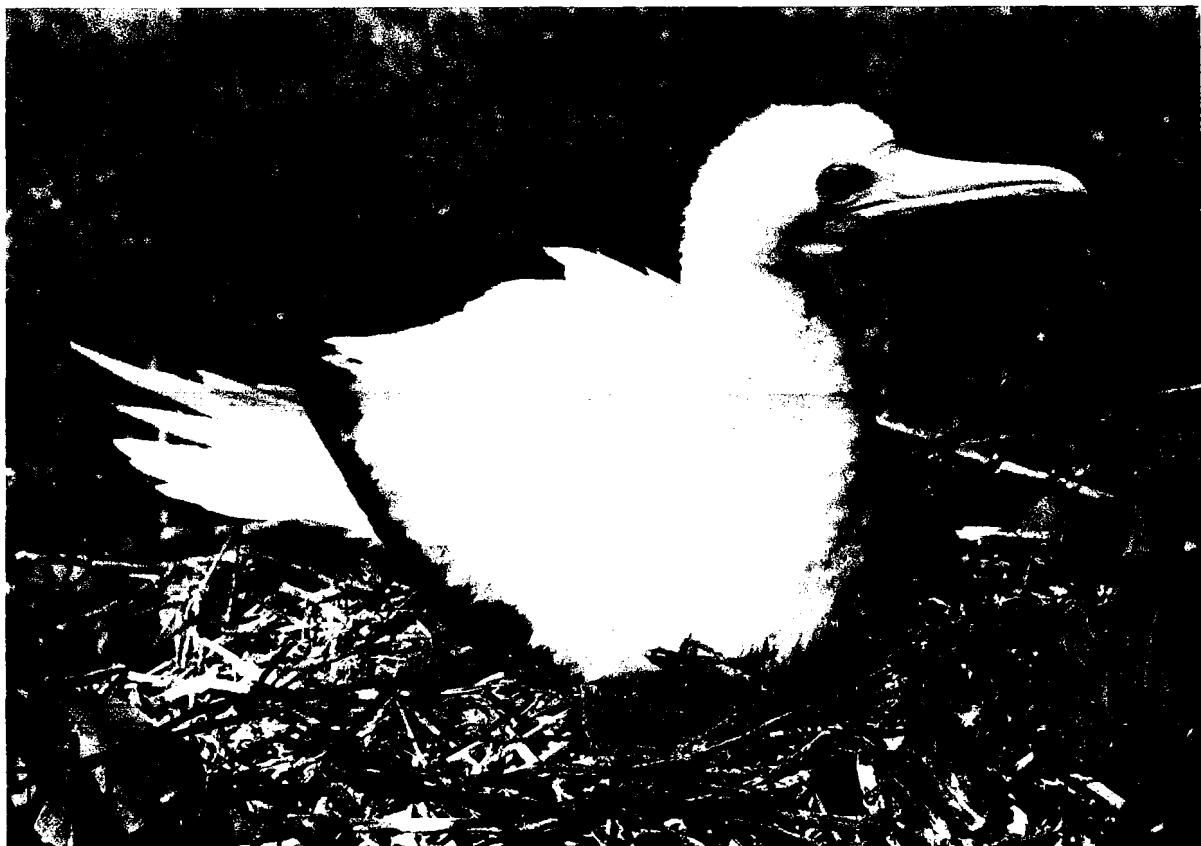
Pl. 27. Masked Gannets on the nest in the central guano area. The nest is simply a depression in the sand.



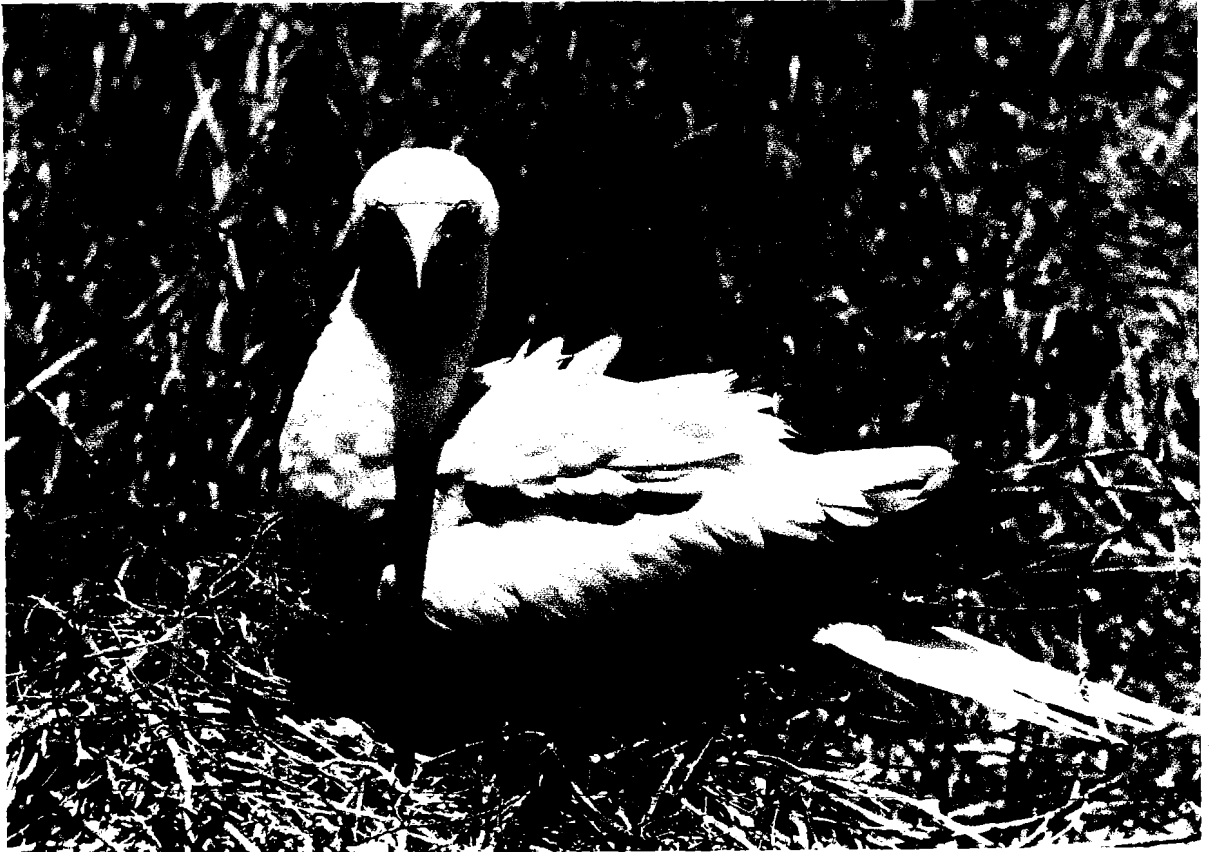
Pl. 28. Hatchling Masked Gannet in the central guano area.



Pl. 29. Hatchling Masked Gannet with regurgitated flying fish  
*Cypsilurus melanocercus* in a nest in the central guano area.



Pl. 30. Red-footed Gannets on nests built on low *Abutilon* shrubs on  
the high ridge at the west end of the island.



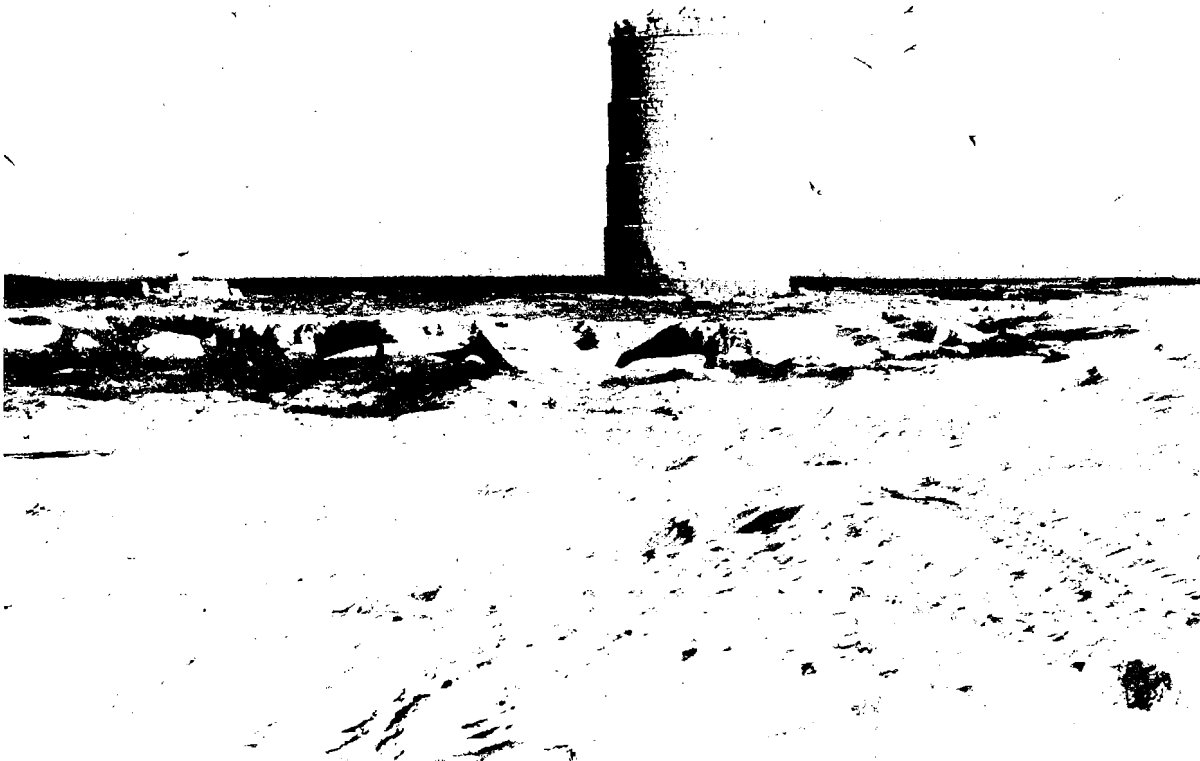
Pl. 31. Red-footed Gannets on nests built on low *Abutilon* shrubs on the high ridge at the west end of the island.



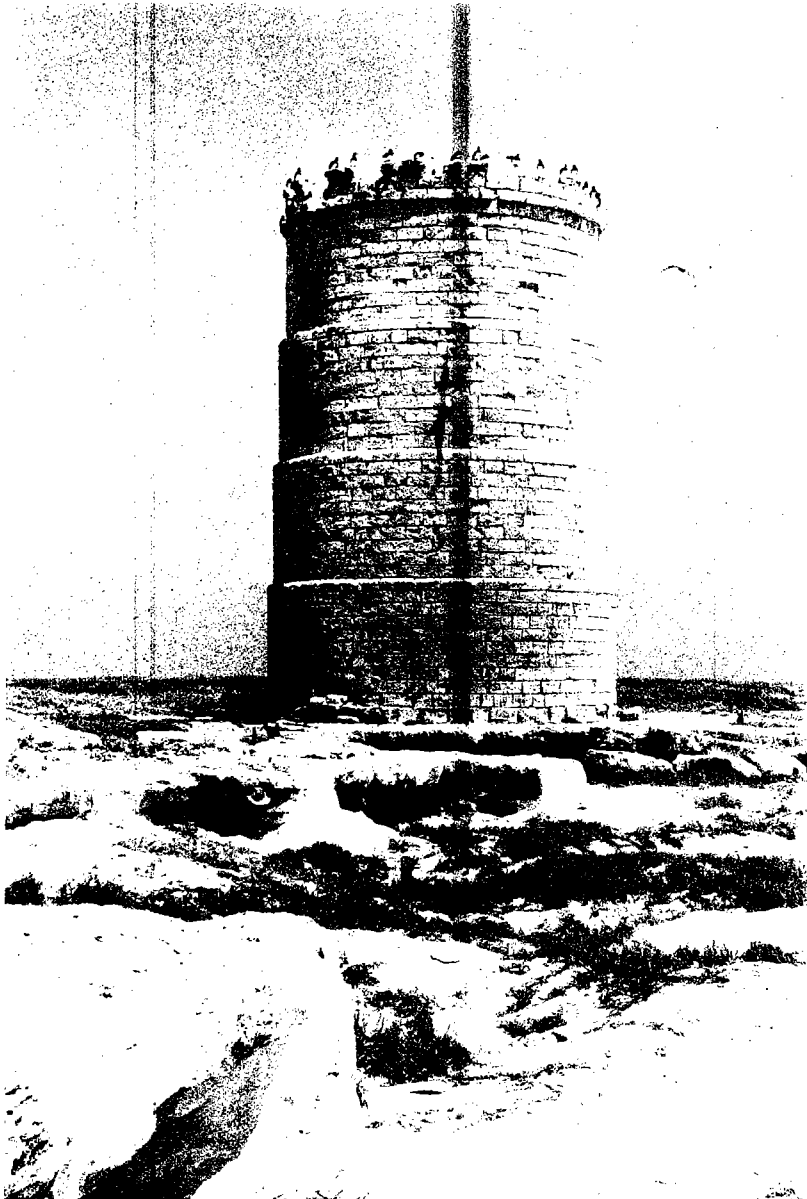
Pl. 32. Fledgling Red-footed Gannet on the nest at the west end of the island.



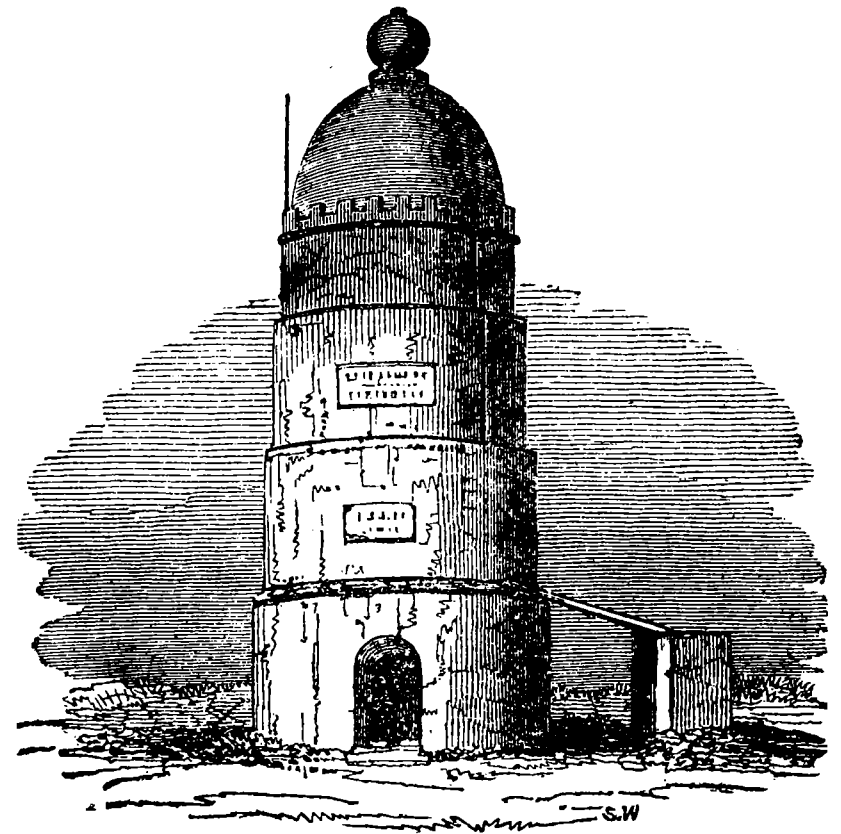
Pl. 33. Juvenile Red-tailed Tropic-bird under the phosphate cliffs at the east end of the island.



Pl. 34. The Beacon and grave at the east end of the island, seen from the south in November 1973.



Pl. 36. The Beacon in November 1973. The dark area on the lower



Pl. 35. The Beacon as erected in 1844, from *Nautical Magazine*,



Pl. 37. Inscriptions inside the walls of the Beacon.



Pl. 38. The grave of Annie Eliza Ellis.