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Forty-five years of change on low wooded islands, Great Barrier Reef

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During the 1928–29 Expedition, centred at Low Isles, Spender mapped the 'low wooded islands' or 'island-reefs' of Low Isles and Three Isles in detail, and additional information was published by Steers, T. A. Stephenson and others. From this work, two different models of the evolution of low wooded islands were proposed, Spender holding that the islands were in a state of equilibrium resulting from their location on the reef, Steers that they could be placed in an evolutionary sequence. Moorhouse described the results of cyclones at Low Isles in 1931 and 1934, and Fairbridge & Teichert reconsidered the general issues following aerial reconnaissance and a brief visit to Low Isles in 1945. Subsequently, aspects of change since 1928–29 have been studied at Low Isles by W. Stephenson, Endean & Bennett in 1954 and by W. Macnae in 1965. Maps produced since 1929, however, have all been based on Spender's surveys. In 1973, Low Isles and Three Isles were remapped in detail, and a direct comparison can now be made over an interval of 45 years. This shows changes in island topography, and substantial alteration in the size and location of shingle ramparts which has affected conditions for coral growth on reef flats. Mangroves have extended greatly at Low Isles, but not at all at Three Isles. The implications of these findings for the general models of Steers and Spender will be discussed and related to the Holocene history of the Great Barrier Reefs.

Introduction

No coral island in the world has been so intensively studied over so long a time as Low Isles, the southernmost low wooded island of the Great Barrier Reef (figure 1). Even before it became the headquarters for the Great Barrier Reef Expedition 1928–29 it had been noticed and described, first by Cook in 1770 (Beaglehole 1955, p. 343), then by King in 1819 (1827, vol. I, p. 207), and by the *Rattlesnake's* naturalist MacGillivray in 1848 (1852, vol. 1, pp. 101–103). In 1928–29 it served as the base for Steers's extensive studies of reef islands, and it was mapped in great detail at a scale of 1:5000 by Spender as a basis for the surveys of the biologists (Steers 1929, pp. 251–253; Spender 1930; Stephenson, Stephenson, Tandy & Spender 1931). The first air photographs available were flown in September 1928 at a scale of 1:2400 and were used in these studies.

Subsequently, note was taken of minor geomorphic changes during storms in 1931 and 1934 (Moorhouse 1933, 1936), chiefly by annotating Spender's map. Steers briefly revisited the island in 1936. New air photographs (1:3000) were flown in January 1945, and these, together with a visit on 30 January–4 February 1945, led to a substantial rediscussion of many features by Fairbridge & Teichert (1947, 1948). This reinterpretation rested rather heavily on the air photographs, for their visit was during neap tides and coincided with bad weather during which rainfall totalled 280 mm. Again the changes were annotated on Spender's map.

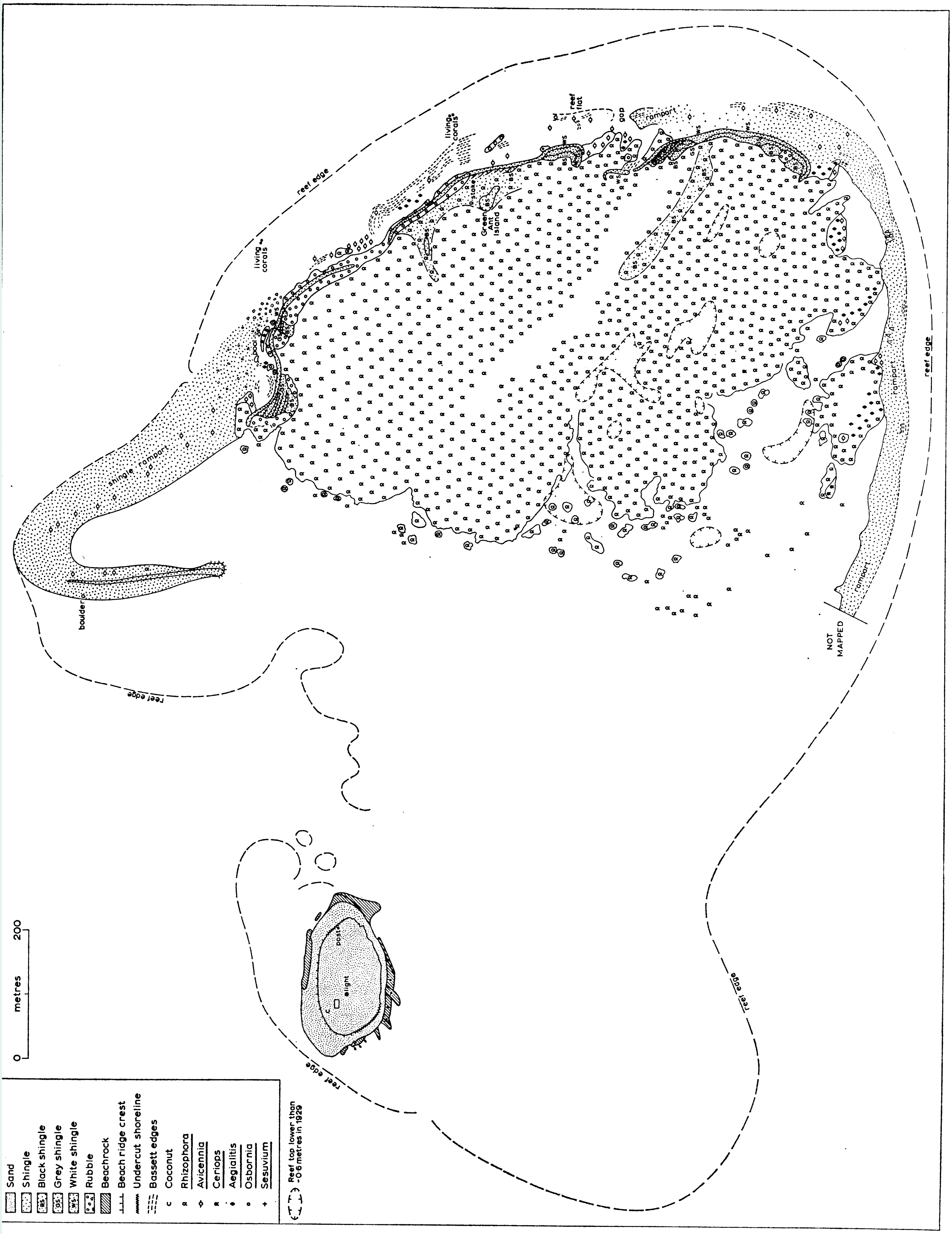

FIGURE 1. Low Isles, 1973.

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Figure 2. Three Isles, 1973.

The next major study was that of Stephenson, Endean & Bennett (1958), during an expedition (12–26 August 1954) organized by the Great Barrier Reef Committee following the cyclone of 1950. Detailed notes were made of changes since T. A. Stephenson's work in 1928–29, but no fresh mapping was undertaken. Subsequent studies included visits to collect marine algae in May 1963 by Cribb (1973), and a visit of a few hours by W. Macnae (1966, pp. 86–88) in March 1965 to observe mangroves.

Table 1. Characteristics of simple low wooded islands

	area of reef top/ha	Total land area at low water springs ha	Land area as percentage of reef top	Area of sand cay ha	Mangrove area/ha
Low Isles	136	37.5	27.5	2.25	32.3
Three Isles	134	47.1	35.2	15.81	8.2
Two Isles	129	33.1	25.7	19.46	1.5
Pipon Isles	334	72.0	21.6	0.74	62.1

Table 2. Elevations of selected geomorphic features of low wooded islands

	Low	Three	Two
highest open-water corals	0.6	0.9	0.4
highest shingle rampart	—	1.1–1.6	1.7
highest living moat corals	—	0.9–1.1	—
lower platform	—	1.7–2.1	1.3–2.1
upper platform	—	2.7–3.1	—
highest old shingle ridge	3.8	—	—
highest mangrove	2.2	1.1	1.8
low terrace on sand cay	—	3.0–3.8	3.4–3.7
high surface on cay	4.2–5.5	4.8–5.9	6.0–6.3
maximum height of cay	5.5	6.0	6.6
height range of beach-rock	1.7–2.7	0.7–2.8	0.6–2.7

Extreme h.w.s. 3.9; m.h.w.s., 2.3; m.h.w.n., 1.6; m.l.w.n., 1.2; m.l.w.s., 0.5; extreme l.w.s., 0. All elevations in metres.

In spite of this level of activity, however, resulting in comprehensive inventories of the biota (Endean 1956; Stephenson & Wells 1956), the only full topographic survey remains that of Spender, and perhaps not surprisingly some of the later visits have yielded contradictory views on the nature and direction of geomorphic changes. The re-survey undertaken in 1973, therefore, aimed to produce a new map from which changes since 1929 could be directly measured. A camp was occupied on Low Isles Cay from 24 to 29 August, during spring tides, and the island was surveyed by tape-and-compass traverse. This method is less rigorous than Spender's original theodolite triangulation, but yields acceptable results for comparison.

Three Isles Reef was also mapped at 1:5000 by Spender (1930), though in less detail than Low Isles. His results were used in the general discussion of low wooded islands by Stephenson *et al.* (1931). Three Isles also had been noted by Cook in 1770 (Beaglehole 1955, p. 371) and was visited by MacGillivray in 1848 (1852, vol. 1, 105 and 106). Agassiz landed there in 1898 and made some characteristically hasty inferences (1898 pp. 113 and 114, pl. 7–11). Steers (1929, p. 256) took the view that Three Isles is perhaps the finest example of what he termed the 'normal case' of low wooded island. Because of the quality of Spender's 1929 map, it was decided to re-map Three Isles in 1973 also (figure 2). A camp was occupied on the cay from

7 to 27 September, though during this time periods were also spent working on Two Isles and Low Wooded Island. The topography was mapped by pace-and-compass traverse.

This paper is confined to an analysis of the geomorphic and ecological changes which have taken place between the detailed surveys at Low Isles and Three Isles in 1928–29 and 1973, together with some references to the very similar features at Two Isles and Pipon Isles, mapped by Steers in 1936 (1938, pp. 75 and 76) and also in 1973. Comparative data are also available on many other low wooded islands, mapped by Steers in 1928–29 and 1936 and again by us in 1973, but these surveys are less detailed and they will be considered elsewhere. Table 1 gives dimensions of the four low wooded islands considered here, and table 2 further geomorphic data; elevations are referred to the Queensland datum (mean lower low water springs).

Problems of interpretation

The results of the re-survey bear directly on the problems of interpretation of the development and history of low wooded islands first identified by Steers (1929, 1930, 1937) and Spender (1930, 1937). Low wooded islands comprise three main elements on the tops of small patch reefs of the Great Barrier Reef Inner Shelf. These are (1) an array of broadly arcuate shingle ramparts round the windward reef rim; (2) a mangrove swamp immediately in the lee of the ramparts; and (3) a leeward sand cay. Low wooded islands differ considerably in the relative extent of these components, the proportion of the reef top occupied by them, and the complexity of the rampart systems. Most low wooded islands have high conglomerate platforms associated with the ramparts; these are present at Three Isles, where they were mapped by Spender, but not at Low Isles, which is to that extent unrepresentative of the class. Steers (1930, 1931, 1937) believed that the conglomerate platforms were derived from lithified shingle ramparts, but owed their present elevation to a slight eustatic fall in sea level. Spender drew no such conclusion; he argued that ramparts advanced as waves of shingle from the reef edge, each reaching a limiting distance before a new one began to form, and that older ramparts then became consolidated. Thus for Steers, though not for Spender, the sequence of ramparts and platforms had historical significance. Steers also believed that the relative extent of mangroves on the reef top (as well as the complexity of the ramparts) indicated the stage of development of the low wooded island complex; Spender thought this view oversimplified, and argued that in at least some cases the postulated sequence might well have been reversed.

These conflicting views were generalized into widely differing interpretations of reef island development and history in the Great Barrier Reef Province. If they can be tested by the detailed remapping of Low Isles, Three Isles, Two Isles and Pipon Islands, then the conclusions drawn at these two locations will have wider significance. We discuss the two reefs together, under the general heads of ramparts, platforms, mangrove swamp, sand cay, and faunistic changes. Figure 1 shows the 1973 survey of Low Isles and figure 2 that of Three Isles. Low has a reef-top area of 136 ha and maximum dimensions of 1.8 and 1.5 km; Three an area of 134 ha and dimensions of 1.7 and 1.2 km; Two an area of 129 ha and dimensions of 1.7 and 0.95 km. At low water, 27.5 % of the reef top is occupied by land (including mangrove) at Low, 35 % at Three, and 26 % at Two.

Ramparts

Spender (1930) mapped an almost continuous zone of shingle ramparts round the windward side of the Low Isles Reef. He distinguished an outer rampart, forming 'a low wall, rising at its inner edge perpendicularly from the flat . . . about 2 to 3 feet [0.6–1 m] high' with 'an even, gradual slope' on its seaward side (Spender 1930, p. 197; Stephenson *et al.* 1931, p. 24). The crest of this outer rampart reached 1.5–2.1 m above datum at Low Isles, compared with less than 1.5 m at Three Isles. In both cases the outer rampart consisted of fresh white shingle. The inner rampart had the same form as the outer, but consisted of blackened shingle with interstices filled with sand and mud; it was colonized by *Avicennia*, *Aegialitis* and *Sesuvium*. Spender interpreted the ramparts as successive waves of shingle driven across the flat by wave action; the rampart moved until it had reached a limiting distance defined by wave strength, and then a new rampart formed to seaward and began migrating inwards. Spender appeared to ascribe rampart formation to ordinary wave conditions rather than to storm events. The average width of the outer rampart at Low Isles in 1929 was about 60 m and the maximum 80 m. At Three Isles the corresponding features was rather less continuous than at Low Isles, especially in the southeast; it also had an average width of 60 m and a maximum width of 70 m. The inner rampart was not readily distinguishable as a distinct entity at Three Isles; at Low Isles it was also about 60 m wide.

In February 1931 heavy southeast winds led to the erosion of the ramparts on the south and southwest sides of Low Isles, with deposition in the southeast. New banks of coral shingle 22 and 30 m long were formed, with steep landward and gentle seaward slopes (Moorhouse 1933). On 12 March 1934 a cyclone pushed the ramparts inwards 23–27.5 m, especially in the northeast. The new banks built in 1931 were flattened, but were rebuilt within two months. These changes had marked effects on coral growth in moats ponded on the landward sides of the ramparts (Moorhouse 1936).

Fairbridge & Teichert (1947, 1948) made a full re-analysis of the Low Isles ramparts in 1945. They distinguished four ramparts. The first (innermost and oldest) was represented by shingle tongues mapped within the mangroves by Spender, but not recognized as a separate rampart by him. The second was equivalent to Spender's inner rampart, and the third to his outer; both in 1945 consisted of blackened and corroded shingle (Fairbridge & Teichert 1948, p. 79). The fourth resembled the 1929 outer rampart in that it consisted of 'fresh, unblackened . . . very light coloured' shingle. It had formed since 1929, in part from the new ridges described in 1931 by Moorhouse. Spender's inner rampart 'had not moved at all' since 1929. The old outer rampart retained much of its original form, but had moved inwards by up to 40 m; on the east side the new fourth rampart was superimposed upon it in two banks each about 250 m long. Taken as a whole the ramparts in 1945 retained their original lateral continuity.

By 1954, however, Stephenson *et al.* (1958, p. 289) drew attention to the absence of shingle on much of the eastern and southeastern sides of the reef, from the level of high water neaps to below low water springs: the former presence of ramparts was indicated only by consolidated bassett edges. Mapping in 1973 confirmed this change, which probably resulted from erosion during the 1950 cyclone. The reef-flat ramparts have disappeared from most of the eastern side of the mangrove island; extensive bassett edges indicate their former locations. The edge of the mangrove itself is lined by a largely symmetrical breastwork of white shingle, overlapping the landward edges of Spender's old inner rampart. The total length of this breastwork is about 1100 m, divided into three main sections. Ordinary ramparts similar to those described by Spender still exist in the south and extreme north, though the northern spit has changed its shape and location; these ramparts are 25–40 m wide. Seaward of the ramparts is a gently sloping reef flat, covered with an algal turf, averaging 40–50 m in width, and with patches of algally bonded shingle. The surviving old dark shingle ridges inside the breastwork are generally

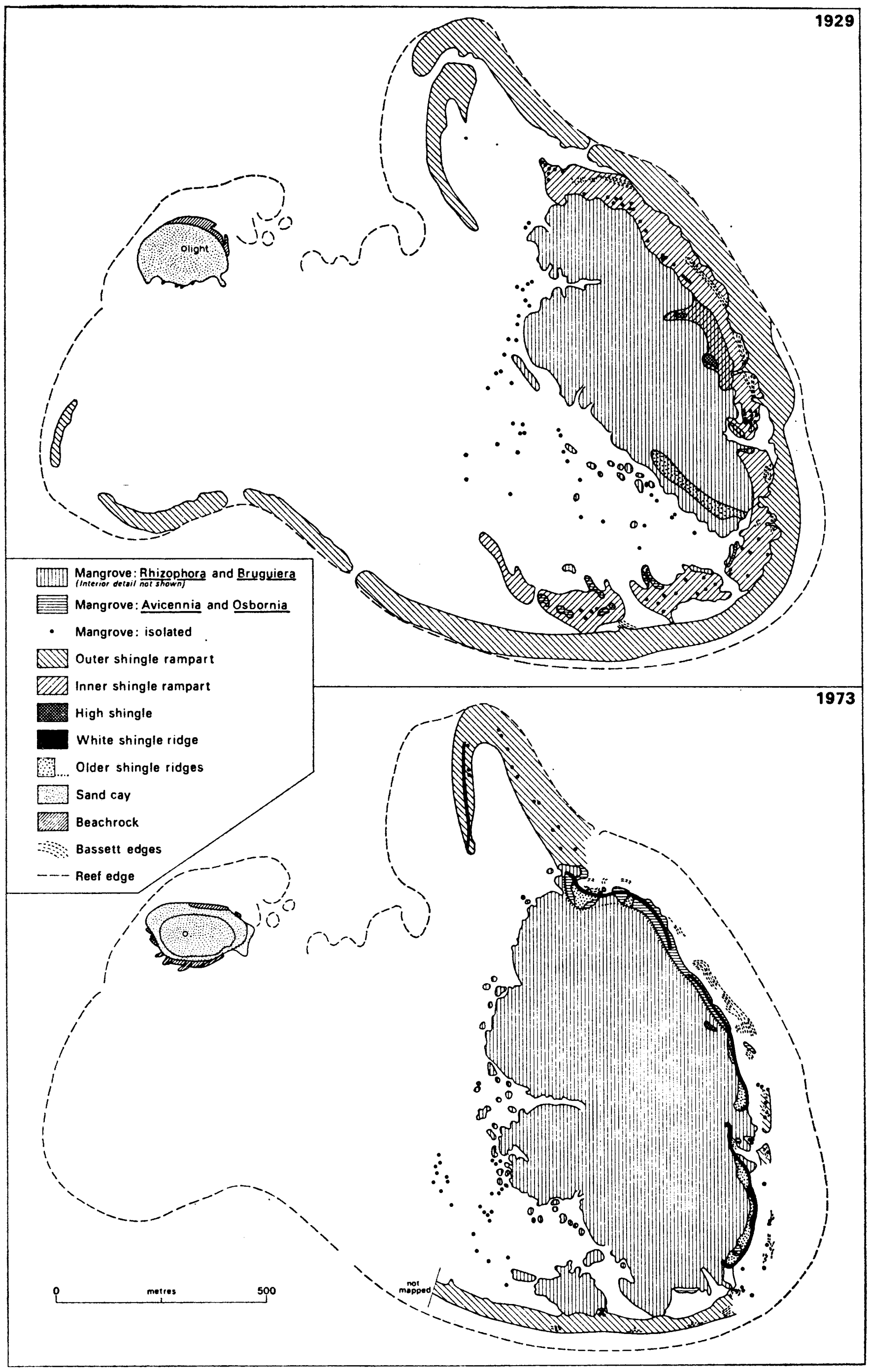

FIGURE 3. Topographic change at Low Isles, 1929–1973.

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20–35 m wide. This major change in rampart form and location presumably results from storm activity, and indicates that rampart evolution is a less regular process than Spender thought. It also shows that superimposition of ridges occurs where their forward movement is checked by the presence of dense mangrove woodland.

Re-mapping at Three Isles (figure 4) shows a very similar situation. A large area of outer rampart has disappeared at the southeast point, leaving bare reef flat. The remainder of the

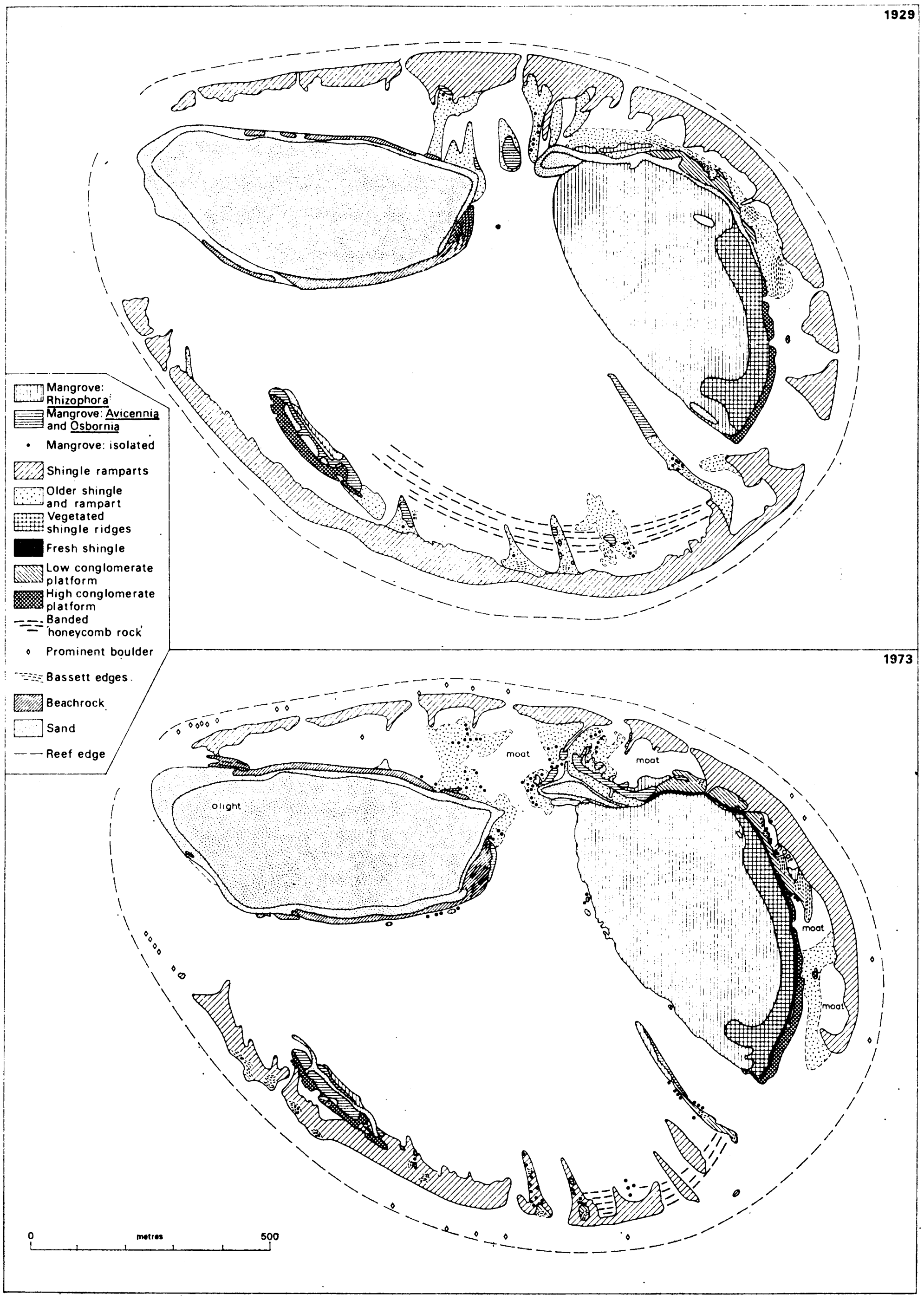

FIGURE 4. Topographic change at Three Isles, 1929–1973.

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rampart retains its general form, though with many more gaps (resulting in draining of moats), but it has also moved considerably forward. This is particularly noticeable at Third Island, where in 1929 the rampart was 60–90 m seaward of the shore and now impinges directly on it. These changes in the inner edge of the rampart are detailed in figure 5. There is no indication at Three Isles of the kind of cyclic development suggested by Spender, but rather a continuing process of redistribution of shingle, interrupted by major storm events which locally strip the reef flats.

Re-mapping at Two Isles also shows major changes in the location of the inner edge of the rampart between 1936 and 1973, especially in the north.

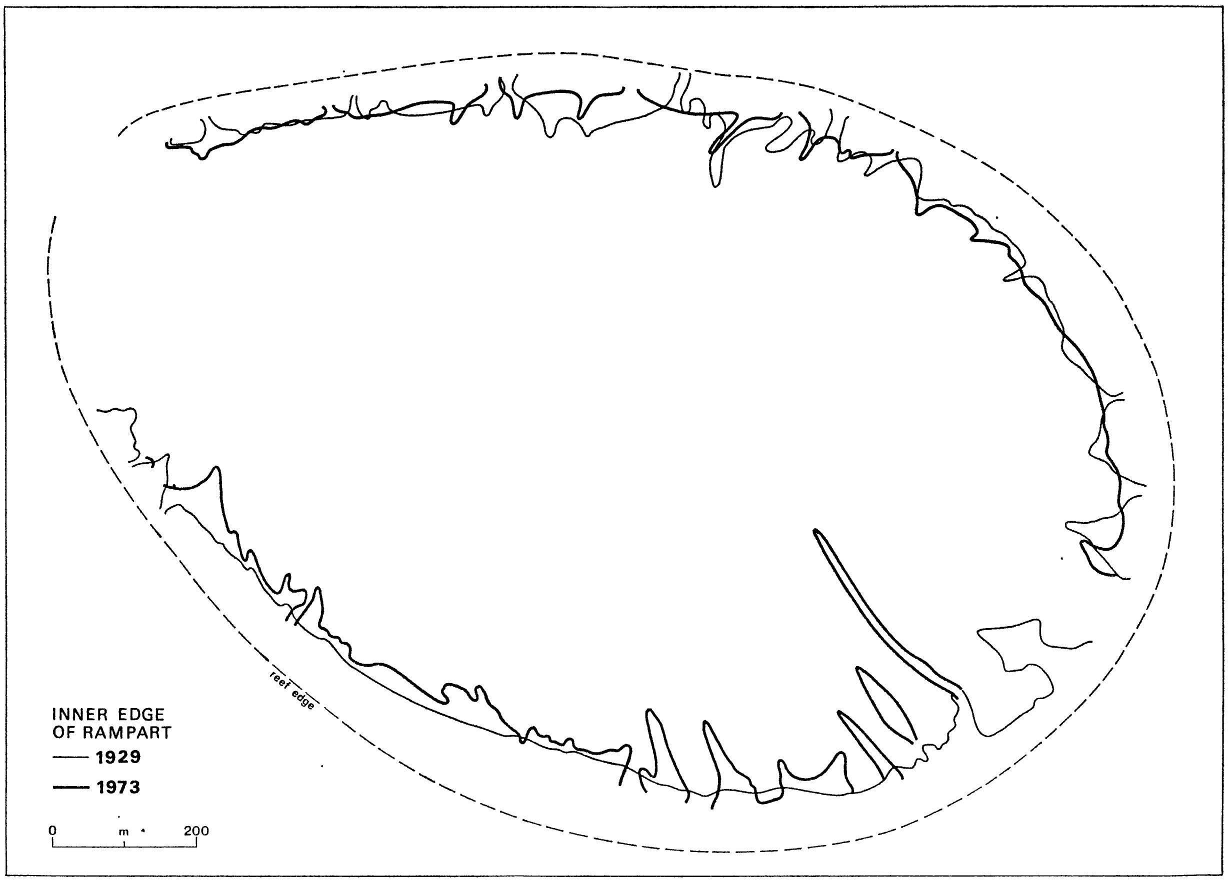

Figure 5. Changes in the Three Isles ramparts, 1929–1973.

Platform

Spender mapped two conglomerate platforms at Three Isles, a high and a low, with a height difference between them of 1.7 m; the high platform ('promenade') was nearly 400 m long (Stephenson *et al.* 1931, p. 30). It was surmounted by 'an accumulation of shingle, sand and pumice forming a dune-like bank about 50 yds wide and probably as much as 20 ft [6 m] above datum', which had no real counterpart at Low Isles. Some dissection of this upper platform had occurred by 1973, especially on Third Island, but otherwise the features remained as mapped by Spender. The height range of the lower platform was determined as 1.7–2.1 m,

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and of the upper 2.7–3.1 m. Where levelled, the shingle bank reached a maximum elevation of 1.6 m above the upper platform, i.e. to 4.7 m. A less well marked platform at Two Isles ranged between 1.3 and 2.1 m; the rock outcrop is 13–25 m wide, and the band of shingle ridges above it is up to 100 m wide. In the case of Three Isles, both Agassiz (1898, pp. 113 and 114) and Spender (1930, pp. 207–210) thought the platform had formerly been more extensive round the windward side of the reefs.

Spender argued from the concordant heights of the Three Isles upper platform and the crest of the Low Isles shingle ramparts that the former was a lithified rampart eroded and cliffed on its seaward side. The lower platform, which frequently breaks down into bassett edges, is more clearly a cemented rampart. Radiocarbon dates have been obtained on a coral from the lower part of the upper platform of 3750 ± 110 a B.P. and on a clam from the upper part of 3050 ± 70 a B.P.; by contrast a clam from the lower platform dates at 1460 ± 70 a B.P. (ANU-1380, 1382, 1475: Polach, McLean, Caldwell & Thom 1978, part A of this Discussion).

Mangrove swamp

The mangrove at Low Isles was mapped by Spender and described by Steers (1929, pp. 254 and 255) and Stephenson *et al.* (1931). A distinction was drawn between the 'mangrove swamp' and the 'mangrove park'. The former consisted of a dense woodland of *Rhizophora stylosa* (*R. mucronata* of the earlier reports) with sandy pools, muddy glades and passages, and some shingle tongues extending inwards from the ramparts. The park, to the southwest of the swamp, was 'that part of the flat which is more or less successfully colonised by outlying trees or samplings of *Rhizophora*' (Stephenson *et al.* 1931, p. 50).

The mangroves were considerably damaged by the 1934 cyclone, but there was no trace of this by 1945. Fairbridge & Teichert (1948, p. 76) concluded that there had been no marked change in the extent of mangrove in the swamp, but they documented the spread of *Bruguiera* on their first rampart and of *Avicennia* on their second. *Avicennia* had extended considerably in the east and northeast, and was also growing on their third rampart. In the mangrove park, on the other hand, the development of *Rhizophora* was 'very noticeable', patches of it 'expanding and coalescing everywhere'. They concluded that it would be 'only a question of time until most of the Reef Flat would be covered with dense mangrove growth' (Fairbridge & Teichert 1948, p. 85).

This spread continued from 1945 to 1954: Stephenson *et al.* (1958, p. 309) noted the wide extension of *Rhizophora* seedlings: to them, 'a slow spreading seems inevitable and . . . eventually the entire flat may be converted into a mangrove swamp'. Nevertheless, in spite of these remarks, Macnae (1966, p. 88) took the view that no significant changes had taken place between 1929 and his visit in 1964; however, he carried out no surveys and made no measurements.

The 1973 map confirms the trends identified in 1945 and 1954 and disproves Macnae's contention. Planimetric measurement (figure 6) gives a total mangrove area of 21.9 ha in 1929 and 36.5 ha in 1973, an increase of 67 %. The 1929 swamp area remains as it was, with the same identifiable pools and channels. Much of the mangrove park, however, has become continuous woodland, though lower and less dense than that of the 1929 swamp. Expansion has been particularly marked along the old ramparts in the south. The present mangrove margin closely follows the shoal areas contoured by Spender in 1929. Spender had suggested that the deeper reef-top pools were erosional and resulted from chemical rotting during the former presence of mangroves (Spender 1930, pp. 8 and 290; also Fairbridge & Teichert 1948, p. 82); he also suggested (1937) that mangroves were retreating from a former wider extent on the southern ramparts. Such retreat on the ramparts could perhaps have resulted from storm activity; but the evidence of change since 1929 clearly shows expansion, not contraction, of the mangrove cover, and also indicates that the pattern of expansion is a function of pre-existing reef-top topography.

The position at Three Isles is quite different: within the limits of the mapping method there has been no measurable change in the extent of the mangrove swamp since 1929; it has remained constant at 8.2 ha. No reason can be given for this difference, though it might be noted that in

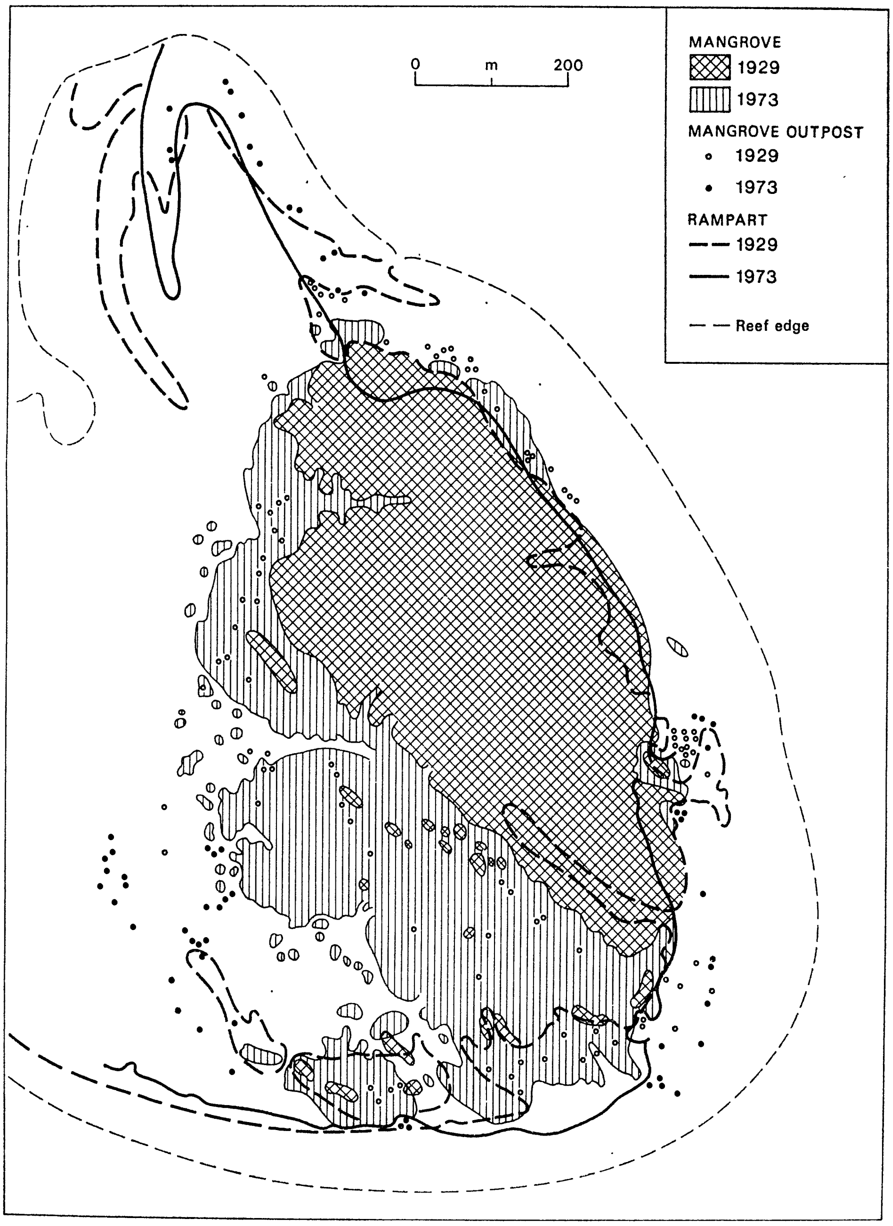

FIGURE 6. Change in the mangrove swamp and ramparts, Low Isles, 1929–1973.

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1929 the edge of the swamp was a wall of tall mangrove, as in 1973, with no spread of seedlings or 'mangrove park' on the flat. Spender (1930, p. 207) himself remarked on this contrast between Low Isles and Three Isles, and suggested that mangrove growth might be limited by factors intrinsic to each particular low wooded island.

Studies in 1973 gave the most complete collection to date of Low and Three Isles mangroves, with information on their distribution. Several species now common have not previously attracted attention. Table 3 lists the species collected at these islands.

Table 3. Mangroves recorded on selected low wooded islands in 1973

	Low	Three	Two	Pipon
Aegialitis annulata R.Br.	×	×	×	×
Aegiceras corniculatum (L.) Blanco	×	—	—	—
Avicennia marina (Forst.) Vierh.	×	×	×	×
Bruguiera exaristata Ding Hou	—	×	×	—
Bruguiera gymnorrhiza Lam.	×	—	×	—
Ceriops tagal (Perr.) C.B.Rob.	×	×	×	×
Excoecaria agallocha L.	×	—	—	—
Lumnitzera racemosa Willd.	—	—	—	×
Osbornia octodonta F.v.M.	×	×	×	×
Rhizophora stylosa Griff.	×	×	×	×
Sonneratia alba J.E.Sm.	—	×	×	×

Rhizophora stylosa is the dominant species, forming a closed forest up to 20 m tall. It is also the pioneer species on the sheltered reef top, and large numbers of seedlings grow in shallow moats enclosed by ramparts; because of the large tidal range these are often more than 1 m tall. This is the species referred to as *R. mucronata* by Spender (1930), Stephenson *et al.* (1931) and Stephenson *et al.* (1958). At higher levels immediately in the lee of the ramparts, especially near Green Ant Island at Low Isles, *Rhizophora* gives way to tall woodland of *Bruguiera gymnorrhiza* (the *B. rheedi* of earlier reports) and *Ceriops tagal*, as described by Fairbridge & Teichert (1948) and Macnae (1966). Macnae also records *Excoecaria agallocha* for this community at Low Isles but this was not collected in 1973. Neither *Sonneratia* nor *Xylocarpus* have been found at Low Isles, though *Aegiceras corniculatum* is present on Green Ant Island, the only location of this species on a reef island of the northern Great Barrier Reef.

The mangrove vegetation of the ramparts is quite different. Most species form dwarf trees and shrubs, except for a tall and extremely dense woodland of *Osbornia octodonta* on the north-eastern flank of the forest. *Osbornia* was not mentioned at Low Isles in 1928–29, and it may possibly have colonized the reef since then; it was recorded at that time at Three Isles. Macnae referred to it in 1964 as a colonizer, with *Pemphis* and *Thespesia*, on rampart crests. In 1973 the rampart had either been removed by erosion or had been pushed inland through the *Osbornia* fringe, so that the trees were growing directly on the reef flat.

The lower ramparts have a characteristic mangrove vegetation dominated by *Aegialitis annulata* and *Avicennia marina* (the *A. officinalis* and *A. eucalyptifolia* of Spender and T. A. Stephenson). Macnae (1966, p. 88) stated that *Aegialitis* had colonized Low Isles since 1929, but this is in error; it was mentioned there by Steers (1929, p. 254), Spender (1930, p. 199) and Stephenson *et al.* (1931, p. 60). Though it can form tall trees, it usually occurs at discrete clumps of shrubs 1–$1\frac{1}{2}$ m tall on older ramparts and bassett edges. *Avicennia marina* is found in similar situations, and rarely exceeds 2 m in height on outer ramparts. Both species can be exposed to severe wave action during high tides and rough weather.

The mangroves of Three Isles are similar, except that *Osbornia* is more extensive and there are large rampart areas of *Aegialitis* and *Avicennia*. Both *Sonneratia alba* and *Bruguiera exaristata* were found at Three but not at Low Isles.

The mangrove associates *Pemphis acidula*, common on conglomerate platforms of low wooded islands, is inconspicuous at Low but extensive on the eastern side of Three Isles. Similarly, presumably because of the absence of suitable substrate, succulent halophytes such as *Suaeda*, *Arthrocnemum* and *Salicornia* are much less extensive at Low Isles than at Three Isles and other low wooded islands.

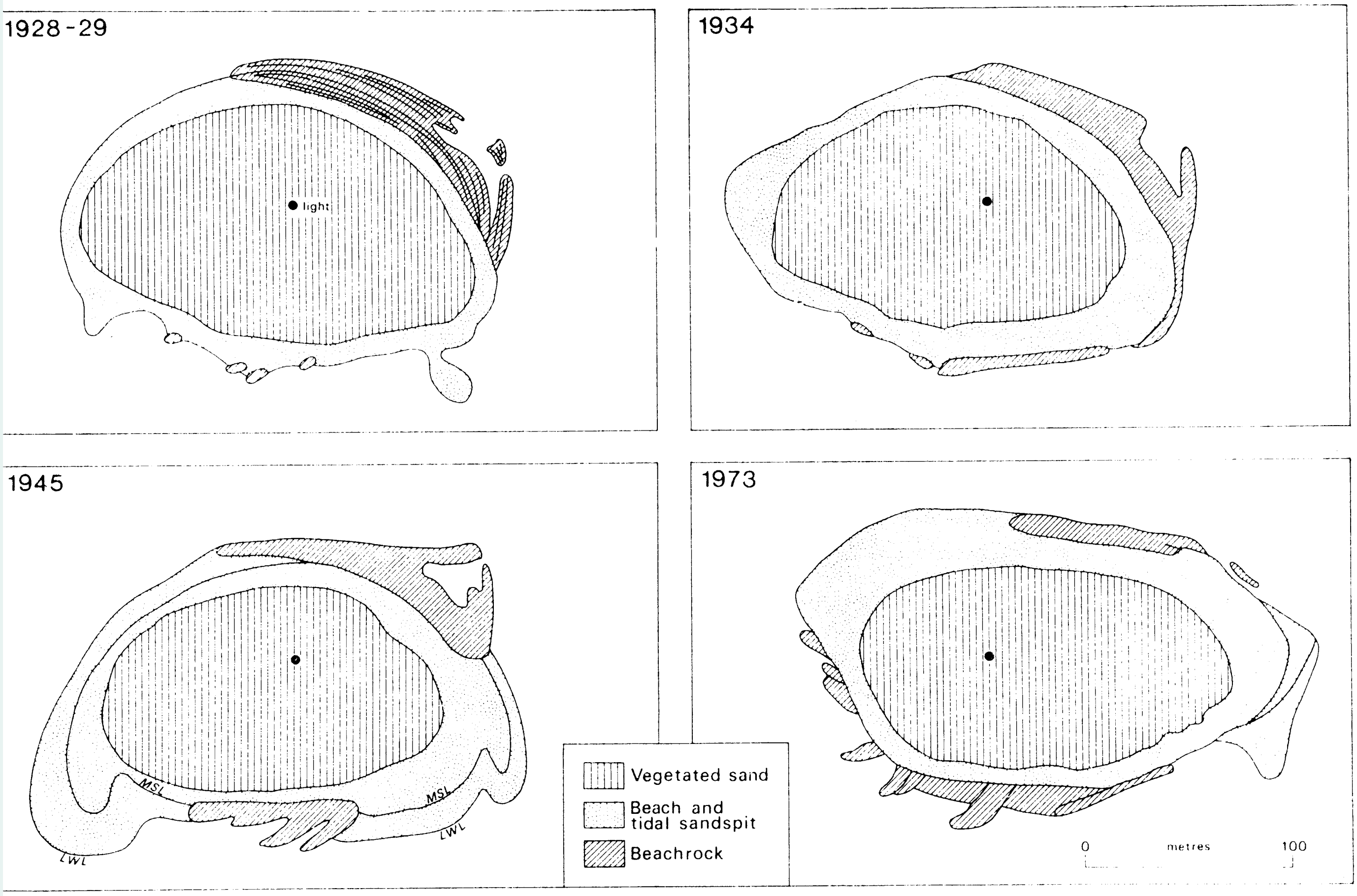

FIGURE 7. Change at Low Isles Cay during successive surveys since 1929.

SAND CAY

The sand cays of the two reefs differ markedly in size: that on Low covers 2.25 ha compared with 15.8 ha on Three. Spender's map of 1929 may be compared with Moorhouse's annotations in 1934, Fairbridge & Teichert's air photograph interpretation in 1945, and the 1973 survey (figure 7). Relative location is established with reference to the lighthouse and the distinctive beach-rock outcrops. In 1928–29 the main beach-rock outcropped in the north, in 1973 in the south. If these maps are superimposed (figure 8) a picture of the range in variation of cay form and the total extent of the beach-rock is obtained (for comments on changes in beach-rock outcrops at other times, see Steers (1937, p. 134), Fairbridge & Teichert (1947, 1948),

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and Stephenson *et al.* (1958, p. 273)). The changes appear to be oscillatory. In part they are doubtless seasonal, in part responses to random storm events. Part of the response may result from changes in the vegetation cover: MacGillivray (1852, vol. 1, p. 101) found the cay 'well wooded' in 1848, but it has long been settled and the vegetation much disturbed.

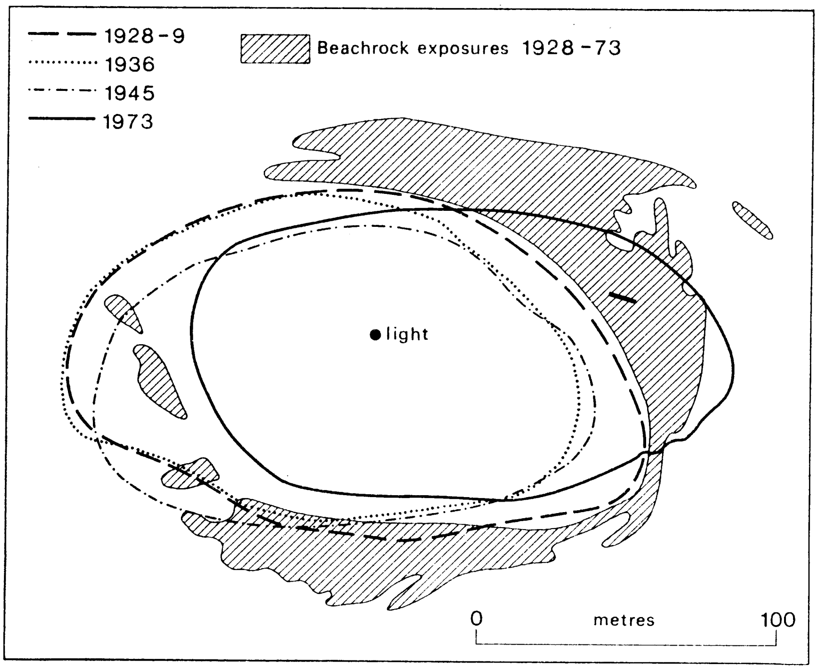

FIGURE 8. Low Isles sand cay, 1929–1973.

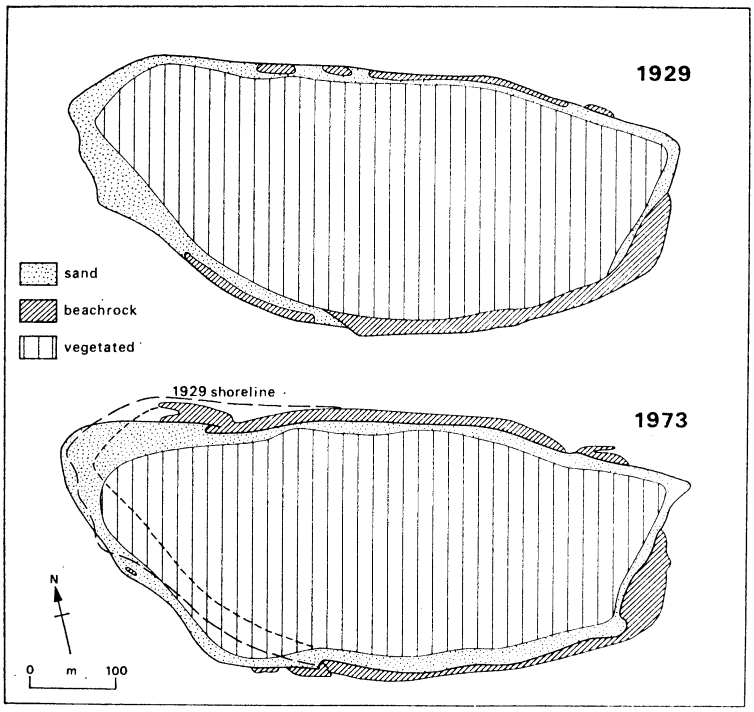

FIGURE 9. Three Isles sand cay, 1929 and 1973.

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Changes at Three Isles are less obvious but more interesting. By 1929 there had been considerable erosion at the east end of the cay, exposing a complex array of beach-rock in front of a tall receding cliff. Since then, more beach-rock has become exposed along the north shore. However, there has also been considerable aggradation on the western end. The 1929 shore can be traced as the backslope of an aggradation terrace covered with pioneer vegetation. Where this backslope reaches the south shore, massive old beach-rock is exposed; it is probably continuous beneath the terrace to the north shore (figure 9). In contrast the beach-rock on the terrace shores is weakly developed and at lower elevations in the intertidal. It is not clear what has triggered this phase of aggradation, nor to what extent it may in part pre-date the 1929 survey.

Similarly, at Two Isles there has been considerable aggradation in the form of low terraces at the east and west end of the cay since 1936, and beach-rock patterns have changed correspondingly (Steers 1938, pp. 75–76): the steep slopes separating the low terrace from the higher densely wooded part of the cay in 1973 coincide almost exactly with the shoreline as mapped by Steers in 1936.

Faunistic changes on the sand flat

Two major faunistic surveys have been carried out at Low Isles: by Stephenson *et al.* (1931) and by Stephenson *et al.* (1958). In view of the geomorphic changes since 1929, we were therefore concerned to identify changes in the sand flat fauna during this period. The sand flat is an extensive area of muddy sand mixed with coral shingle (Flood & Scoffin 1978, part A of this Discussion), extending to a depth of 1.5 m (Marshall & Orr, 1931) and colonized by various marine angiosperms, notably *Thalassia hemprichii* (Ehren.) Aschers., together with *Halodule uninervis* (Forssk.) Aschers., *Halophila ovalis* (R. Br.) Hook., and *Enhalus acoroides* (L.f.) Royle. An account of the fauna collected in 1973 is given elsewhere (Gibbs 1978, this volume). A comparison of the relative abundance and species composition found during this survey with those described in the earlier surveys is difficult for a number of reasons (cf. Stephenson *et al.* 1958), but primarily because the fauna is very diverse in species, many of which occur only as scattered individuals, relatively few being abundant. Also, the earlier accounts are rather brief, the sand flat fauna being investigated as part of broad surveys of the whole reef flat. However, confining comments to the more conspicuous species of the macrofauna, it may be noted that the most common of the surface-burrowing gastropods are still *Cerithium vertagus* L. and *Nassarius coronatus* (Bruguière) together with *Rhinoclavis asper* (L.), *Strombus gibberulus* L. and *Polinices pyriformis* (Recluz). Other nassariids, strombids and naticids are present in fewer numbers along with *Terebra* spp. and *Oliva* spp. Ubiquitous echinoderms such as *Archaster typicus* Müller and Troschel and *Holothuria atra* Jaeger remain common.

The burrowing species composing the infauna are more varied. The presence of certain species can be seen from characteristic disturbances of the sand surface; these species include the enteropneusts *Balanoglossus carnosus* (Willey) and *B. australiensis* Hill (= *Ptychodera flava* Eschscholtz of earlier accounts?) which seem to be as locally abundant as formerly reported, as are the large stomatopod *Lysiosquilla maculata* (Fabricius) and the burrowing holothurian *Holothuria arenicola* Semper. Curiously, another burrowing crustacean, *Axius* (*Neaxius*) sp. cf. *plectrorhynchus* Strahl, which is quite common on the flat, does not appear in the earlier collections (see McNeill 1968). Numerically, the infauna is still dominated by the actiniarian *Edwardsia* (chiefly *E. gilbertensis* Carlgren) and chaetopterid polychaetes. Of the latter, only *Mesochaetopterus sagittarius* Claparède (= *M. minutus* Potts) was found in the earlier surveys, but in 1973 two other genera, *Phyllochaetopterus* and *Spiochaetopterus*, were also very common, as was the terebellid *Pista typha* Grube. On the other hand, sipunculans and *Phyllodoce malmgreni* Gravier were reported as being very plentiful in sand in 1928, but few of the former and none of the latter could be found in 1973.

Although these differences in the relative abundance of certain of the more conspicuous species become apparent when comparing the results of the several surveys, they may reflect short-term fluctuations in populations rather than major changes, and in general the fauna of the Low Isles 'sand flat' appears to have altered little since 1928. However, it should be pointed out that a common sublittoral spatangoid, *Maretia planulata* (Lam.), may have colonized the intertidal deposits adjacent to the Anchorage on Low Isles between 1928–29 and 1954 (Endean 1956), and was still common in 1973 in this same area, along with the clypeastroid *Laganum depressum* Lesson. Spatangoids are noted for their particular substrate preferences (Nichols 1959), and the colonization by *M. planulata* of the tidal flat adjacent to the Anchorage between 1928 and 1954 possibly reflects a subtle change in the character of the sediments in this area during this period.

Implications

These new data indicate that geomorphic processes at Low Isles are less regular and predictable than either Steers or Spender proposed. So far as unconsolidated features such as the inner and outer ramparts first described at Low Isles are concerned, it is clear (*a*) that they do not have historical significance in the sense of indicating specific sea level events, and (*b*) that their formation and destruction takes place irregularly but in geological terms rapidly, in response to random storm events. Mangrove growth on the reef top may indicate a process of extension over time, but the time scale which calibrates it varies widely from reef to reef: in this sense the mangroves are opportunistic colonizers of a substrate of varying suitability. Hence while we agree with Fairbridge & Teichert's conclusion that 'these various reef types present stages in an evolutionary process which led inevitably from the submerged reef stage, through the formation of a sand-cay and the establishment of a mangrove forest on the rampart-protected Reef Flat, to the end stage at which the entire reef platform is covered with vegetation' (1948, p. 85), this concept has little explanatory value in comparing low wooded islands because of the variations in physical conditions between them and the differences in rate parameters that these imply.

Certain basic questions raised by Steers and Spender at Low Isles deserve comment. Which forms first, the sand cay or the ramparts? Is the development of the swamp contingent on the existence of the ramparts? It is likely that the formation of a *Rhizophora* swamp close to the windward edge of a reef could not take place without the protection of the ramparts, as Spender (1930, p. 201) concluded: on islands such as Murdoch and Hampton, where there is *Rhizophora* without ramparts, the swamp is on the lee end of the reef. The only mangroves normally found without the protection of ramparts are *Aegialitis* and *Avicennia*, and these are usually rooted in old rampart conglomerate and rubble. However, the changes at Low Isles show that the existence of the swamp, especially at the high levels to which it can build, checks the inward movement of shingle and concentrates it in a zone of banded breastworks. These usually support a dry-land scrub of *Thespesia*, *Pandanus* and other trees and shrubs. Without the physical barrier of the swamp it is likely that the shingle would form more diffuse and ephemeral constructional features.

It is difficult to find compelling evidence for Spender's suggestion that reef-top mangroves might be decreasing rather than increasing in area, and that 'this might have happened at Low Isles and has happened at Three Isles' (1937, p. 142). At Low Isles the suggestion comes from King's statement (1827, vol. 1, p. 207) that in 1819 there were 'distinctly three' islands, confirmed by MacGillivray (1852, vol 1, p. 101), two of them being 'merely groves of mangrove on the reef'. Spender suggested that one of these groves, now disappeared, formerly existed on the inner rampart at its southernmost location; this is in fact one of the areas extensively colonized since 1929. The deeper reef-top holes, rather than being eroded by organic acids associated with former mangroves, more probably result from inequalities of reef formation which themselves control the location of mangrove growth. Spender's suggestion at Three Isles comes from his inferred fragmentation of previously more continuous ramparts, giving greater exposure on the flat and presumed regression of the mangroves; there seems to be no other direct evidence for former mangrove extension.

Whether the sand cay forms before or after the ramparts is probably not a question to which there is a general answer. On any reef the formation of ramparts and other features must affect patterns of wave refraction and water movement over the reef top, and the cay presumably adjusts to such changes. More important, as a greater proportion of the reef top is occupied by ramparts and mangroves, production of calcium carbonate sand must decline (McLean & Stoddart 1978, part A of this Discussion). Radiometric dates on many islands indicate that most cay sands are about 3000 years old; one from the Three Isles cay gives an age of 3220 ± 80 a B.P. (ANU-1414). It seems that cays formed rapidly in leeward situations once the level of the reef top and of sea level coincided, but that sediment supply subsequently diminished. The existence of low terraces round the Three Isles cay could possibly partly result from this decrease in rate of sand supply as well as from changes in wave pattern and possible slight negative shifts in sea level.

The differing degree of development of conglomerate platforms on different reefs requires comment. There is a well developed 'upper platform' reaching 3.1 m at Three Isles, and an extensive 'lower platform' reaching 2.1 m. There is a platform at Two Isles within the height range of the Three Isles lower platform. There are no platforms at all on Low Isles. If the platforms indicate successively lower stands of sea level, as Steers (1931) suggested, it is difficult to see why there should be these differences on such otherwise similar reef tops.

Conclusion

The sequence of changes outlined here illustrates the complexity of the recent history of low wooded islands and the difficulties of proposing simple models of their evolution. The Queensland examples differ considerably from those of Djakarta Bay (Umbgrove 1929) where the sand cay occupies a much greater proportion of the flat and where the ramparts are much more mobile features (Vertappen 1954). In this Indonesian case Umbgrove suggested that the size of the cay might provide an index of the stage of topographic development of the complex. We have already discussed reasons why stage of mangrove development does not provide a satisfactory index of development. Steers (1937, p. 145) suggested that the width and extent of ramparts might prove a more useful indicator, but our evidence suggests that in this stage of our knowledge such indexes would be simplistic. Continued monitoring at Low Isles and Three Isles will hopefully continue to throw light on present processes and rates of change, which which ultimately could be used to calibrate the recent geomorphic record.

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