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## Long-term trends in the status of coral reef-flat benthos - The use of historical photographs

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### Summary

Recently, there has been wide-spread concern that the coral reefs of the Great Barrier Reef (GBR) have suffered severe degradation from anthropogenic influences since European settlement in Australia. This concern has developed particularly in more recent times, as the human population has increased. Part of the evidence used to support this contention has come from comparisons between old photographs of reef-flats exposed at low tide and the same reef-flats as they are today. This technique is clearly relatively crude and can only be expected to detect gross shifts in benthic community structure. However, it is exactly this kind of change (for example from hard coral dominated to soft coral or algae dominated) that is of interest in the context of 'severe degradation'. Where such photographic comparisons have been used, typically only a small number of old photographs from one or two sites within the GBR have been employed.

The Historical Photographs Project of the Great Barrier Reef Marine Park Authority (GBRMPA) represents the only concerted attempt to use as many old photographs as possible from as many different locations as possible in order to fully assess the information that can be derived from such photographs.

There were two main aims of the project: firstly, to create as comprehensive as possible a collection of historical photographs of the GBR, using only photographs that show below-water substratum and to which an exact geographic location can be ascribed, and secondly, to return to the sites of as many of the original photographs as possible and take new photographs of the same areas of substratum.

In total, comparisons between historical photographs and modern observations can be made for 14 locations. Of the 14 locations for which comparisons can be made, six show no evidence of change in reef-flat benthic communities between the historical photographs and modern observations. These locations are Daydream Island, Magnetic Island, Great Palm Island, Orpheus Island, Fantome Island and Pickersgill Reef. Communities at these locations range from being dominated by *Acropora* spp. to being dominated by a mixture of massive hard corals (mostly faviids and *Porites* spp.) and soft corals. At four locations (Stone Island, Bramston Reef, Fitzroy Island and Michaelmas Cay) evidence of significant change in reef-flat communities has been found. At all four locations there is markedly less living hard coral on the reef-flat today than can be seen in the historical photographs. At least two of these locations have been badly affected by cyclones. At the four remaining locations (Hayman Island, Green Island, Double Island and Low Isles) some areas show evidence of change in the reef-flat community and others appear unchanged from the historical photographs.

Comparisons between historical and modern photographs can provide information that is useful in the management of the Great Barrier Reef World Heritage Area (GBRWHA). Such comparisons can be used to distinguish between reef-flats that should be of concern to managers and others that may require less attention. However, using comparisons between modern and historical photographs as a measure of reef-flat health is a coarse tool with several important limitations (such as only reef-flats near a recognisable landmark can be studied, non-

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randomness of original 'sampling', absence of quantitative data and incompleteness of the temporal record). These limitations must be considered when considering photographic comparisons.

Given the limitations of this technique, comparisons between historical photographs and modern reef-flats can never provide definitive, stand-alone proof one way or the other in the debate over whether or not the GBR is undergoing a steady decline. Clearly, some of the reef-flats studied have suffered heavy mortality of hard corals. However, from the results of the project so far, the large number of locations that do not appear to have changed since the historical photographs were taken throws doubt on the proposition that the GBR is subject to broad scale decline.

## **Introduction**

For over a century, people have been taking photographs of the GBR. The first extensive collection of high quality photographs of coral reefs was produced by William Saville-Kent (1893). The book contains many photographs of the GBR taken at spring low tide. One of Saville-Kent's ambitions in publishing these photographs was that they should be used to monitor the growth of corals in the future. To this end, he made detailed notes about the locations of each photograph, and, in one case, even made a schematic diagram of the corals shown in the photograph with measurements of their sizes. In addition, many of the photographs have distinctive landmarks on the horizon, a further aid in relocation. Despite the existence of this impressive collection of photographs and the explicitly stated intention that they be used to examine coral growth, there exists no published record of an attempt to revisit the sites of Saville-Kent's photographs and take modern photographs for comparison. However, a site near Bowen where Saville-Kent had taken photographs of extensive hard coral formations was revisited in 1925 by Charles Hedley (Hedley 1925). Unfortunately, Hedley did not take further photographs, but his description of the site is very graphic: '... this famous, wonderful, and immense structure has now completely vanished. Not only has the coral all died, but every vestige of it, except the foundation, has been swept away.' This account clearly begs the question 'What would a modern photograph of the area show?'

Since Saville-Kent's book, 100 years have passed and tens of thousands more photographs of the GBR have probably been taken. In most of these the tide is too high to see the reef-flat substratum. In those where substratum is visible, only a few offer the opportunity to relocate accurately the site of the photograph. However, a certain number of photographs exist where reef-flat substratum is visible and the site of the photograph can be relocated. These photographs offer an unrivalled opportunity to compare reef-flats as they are today with reefs as they were many years ago.

Comparisons between historical photographs of coral reef-flats and modern observations have been used before (e.g. Endean 1976; Bell and Elmetri 1995). These comparisons have come from sites including Stone Island (near Bowen), Magnetic Island and Low Isles. In all cases, these comparisons have shown decreases in cover of hard coral and increases in cover of soft coral and/or macroalgae. Typically, these changes in reef-flat benthos are described as reef 'decline'. In some cases the proposition that reefs are declining or dying is extended to the entire GBR. However, these assertions typically are made on the basis of only one or two historical photographs from only one or two sites. The environmental pressure considered most likely to be causing such decline is eutrophication and/or increased sediment load.

No intensive and comprehensive study of historical photographs has yet been carried out. The Historical Photographs Project of the GBRMPA was instigated in order to fill this gap.

The project had two main aims:

1. To create as comprehensive as possible a collection of historical photographs of the GBR, using only photographs that show below-water substratum and to which an exact geographic location can be ascribed.
2. To return to the sites of as many as possible of the original photographs and take new photographs of the same areas of substratum.

## **Materials and methods**

### **Collection of historical photographs**

The libraries of GBRMPA, the Australian Institute of Marine Science and James Cook University of North Queensland were exhaustively searched for published material containing historical photographs. Various other sources were also investigated, for example, private collections of individuals who have worked on the GBR for many years and museum collections. However these sources were not investigated as thoroughly as the libraries.

In order to be acceptable for use in the project, each photograph had to fulfil the following criteria:

- each photograph had to depict coral reef substrate exposed above water; and
- each photograph had to contain a distinctive landmark that would allow relocation of the site of the photograph. Some photographs without landmarks were included, but only if they were part of a set of photographs, at least some of which did contain landmarks.

Photographs were used irrespective of the year in which they were taken in the hope of developing a collection that contained relatively recent photographs as well as very old ones.

All suitable photographs that were discovered were copied using three formats: colour slide, colour print and black and white print. In addition, two large (approximately A4: 297 mm x 210 mm) prints of each historical photograph were made for use in the field.

### **Relocation of sites**

Historical photographs were found associated with widely varying amounts of geographical information. The process of relocating the site of a photograph depended entirely on the quantity and quality of this information. Typically, text found with the photograph gave a rough indication of the location. Usually, this location was then narrowed down by consultation with people familiar with the area (usually staff of the Queensland Department of Environment, the Queensland Boating and Fisheries Patrol, the Queensland Department of Primary Industries and the GBRMPA). Final decisions as to the exact site of a photograph were taken on site at spring low tide. Field work was carried out in 1994 and 1995, during the winter, when the lowest tides occur during the day. Tides used for site visits and photography ranged from 0.02 m to 0.31 m above Lowest Astronomical Tide (LAT).

## **Results**

### **Collection of historical photographs**

In total 121 suitable historical photographs were found. These ranged from Thursday Island in the north to Heron Island in the south and dated from as far back as 1890. Of these 121 photographs, 96 have been copied and added to the image collection of the GBRMPA. The 25

photographs that were not copied were all from the Torres Strait. All locations for which photographs were found are listed in Table 1, together with the numbers of photographs for each location. The positions of each of these locations are shown in Fig. 1.

#### Relocation of sites

For most of the historical photographs, it was not possible to determine exact sites on the reef-flat. Most of the landmarks in the historical photographs are sufficiently far away from the site of the photograph that movement in the order of 500 m on the reef-flat has little effect on the appearance of the landmarks. The problem with distance between site of photograph and useful landmarks also affected the taking of bearings for relocation of the modern photographs. Thus, in most cases, the modern photographs are representative photographs of the same reef-flat as in the historical photograph, not exact replicas of the site of the historical photograph.

#### Interpretation of photographs

The following accounts of individual locations only cover those locations which have been revisited and for which modern information is available. Locations for which historical photographs have been found, but which have not been revisited (see Table 1) are not considered. In addition, no account is given for Border Island. When this location was visited, it was realised that the historical photograph had been taken when the tide was not at its lowest and a large part of the reef-flat was underwater. The accounts of individual locations are general in nature. For specific details of times and dates of photography, tidal heights etc. see Wachenfeld (in press).

#### Daydream Island

The single historical photograph from Daydream Island depicts a substratum of arborescent and caespitose *Acropora*. The exact year in which this photograph was taken is uncertain but the photograph was taken from a book published in 1950, so was certainly taken before that year. This area of the reef-flat still has similar corals to those shown in the historical photograph, with a band of *Acropora* approximately 100 m long and up to 10 m wide along the seaward edge of the reef-flat (Fig. 2).

#### Hayman Island

The three historical photographs from this location were taken in 1946 and depict the same area of the reef-flat. The benthos is dominated by extensive cover of branching hard corals, although the photographs are of insufficient quality to determine any detail. This is the only location at which the exact site of the historical photographs was relocated. Distinctive rocks in the middle distance of the historical photographs were found and thus the modern photographs are of exactly the same area of reef. The living coral in the foreground and middle distance of the historical photographs is no longer present. These areas are now covered predominantly in coral rubble. However, large areas of branching hard corals (caespitose *Acropora* spp.) are present nearer to the seaward edge of the reef-flat. Thus, the area of branching hard coral on the modern reef-flat appears to be less than that in 1946, although extensive areas of the reef-flat are still covered in such corals. It should be noted that a nearby area of the seaward edge of the reef-flat has a different benthic community comprised of a mixture of corymbose *Acropora* spp., massive corals (mostly faviids) and soft corals (mostly *Sinularia* sp.).

**Table 1.** Numbers of historical photographs found, copied and relocated and re-photographed for each location. Where possible, names of locations are followed by the relevant GBRMPA identification numbers.

Location	Number of Historical Photographs Found	Number of Historical Photographs Copied	Number of Historical Photographs Re-photographed
Heron Island 23-052	4	4	0
Wistari Reef 23-053	5	5	0
Daydream Island 20-035	1	1	1
Hayman Island 20-014	3	3	3
Border Island 20-067	1	1	1
Lindeman Island 20-090	1	1	0
Saddleback Island 20-015	3	3	0
Bramston Reef 20-005	5	5	5
Stone Island 20-004	9	9	9
Magnetic Island 19-009	6	6	6
Great Palm Island 18-054	8	8	8
Orpheus Island 18-049	8	8	8
Fantome Island 18-053	1	1	0
Palm Islands (unknown)	2	2	0
Fitzroy Island 16-054	1	1	1
Green Island 16-049	12	12	10
Double Island 16-047	2	2	2
Michaelmas Reef 16-060	3	3	3
Alexandra Reefs 16-039	1	1	0
Low Isles 16-028	12	12	3
Pickersgill Reef 15-093	3	3	3
Watson Island 14-068	1	1	0
Thursday Island	25	2	0
Warrior Island	2	0	0
Unknown	2	2	0
<b>Total</b>	<b>121</b>	<b>96</b>	<b>63</b>

#### Bramston Reef

Five historical photographs from Bramston Reef (a mainland fringing reef, just south of Bowen) were found. All five were taken by William Saville-Kent circa 1890. Because the landmarks in these photographs are poor, the modern versions of all five historical photographs must be considered as general comparisons, rather than specific ones. Despite the inability to relocate the sites of the historical photographs exactly, comparisons are still valid because the modern reef-flat is fairly homogeneous.

All five of the historical photographs show many large colonies of massive corals such as *Porites* and faviids and tabular/corymbose colonies of *Acropora* spp. No such *Acropora* spp. are present currently and although large numbers of faviid colonies are still present, the vast majority are dead and those that are alive are comparatively small (< 15 cm diameter). The dead faviid colonies are typically covered in algae and/or mud. Some living large colonies and micro-atolls of *Porites* are present. The *Porites* micro-atolls present are alive around the sides, with mud and algae on top of them. Some areas of the reef-flat are covered in large amounts of rubble from branching corals and several dead colonies of *Acropora* were found cemented to the reef-flat, apparently where they had grown.

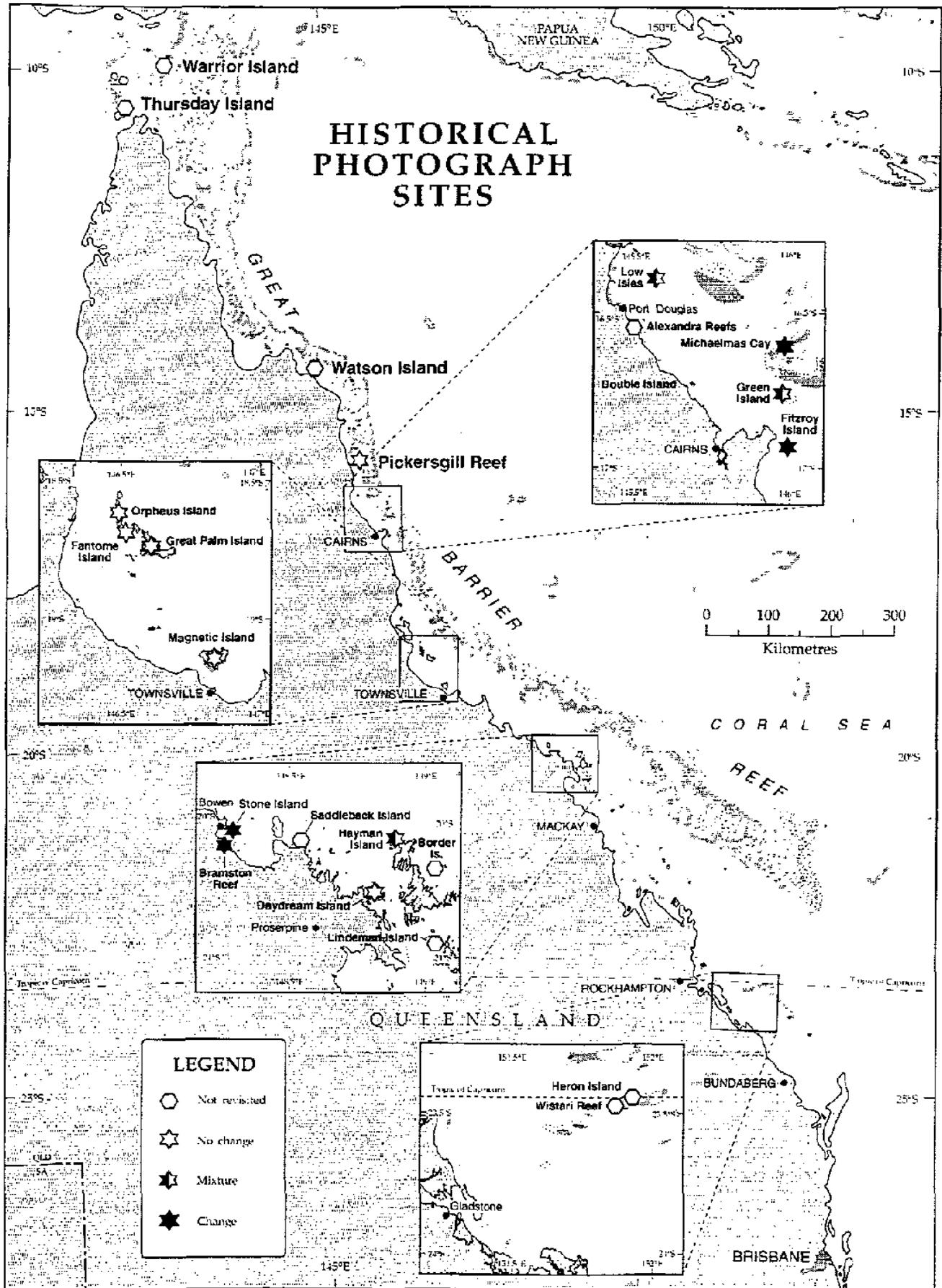
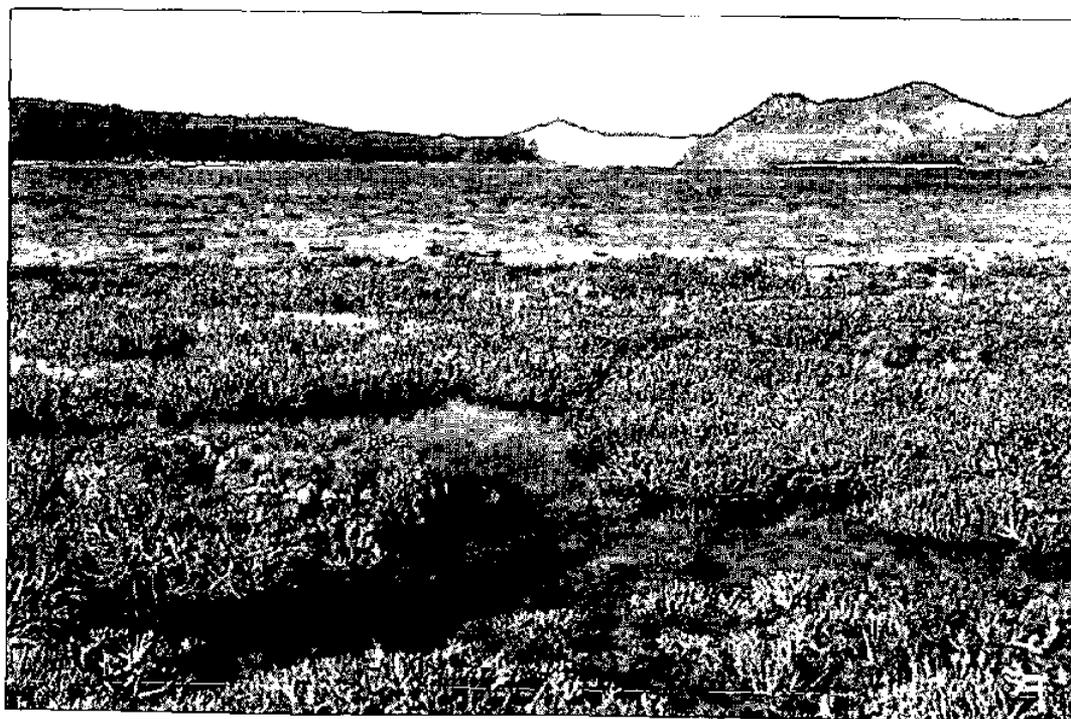
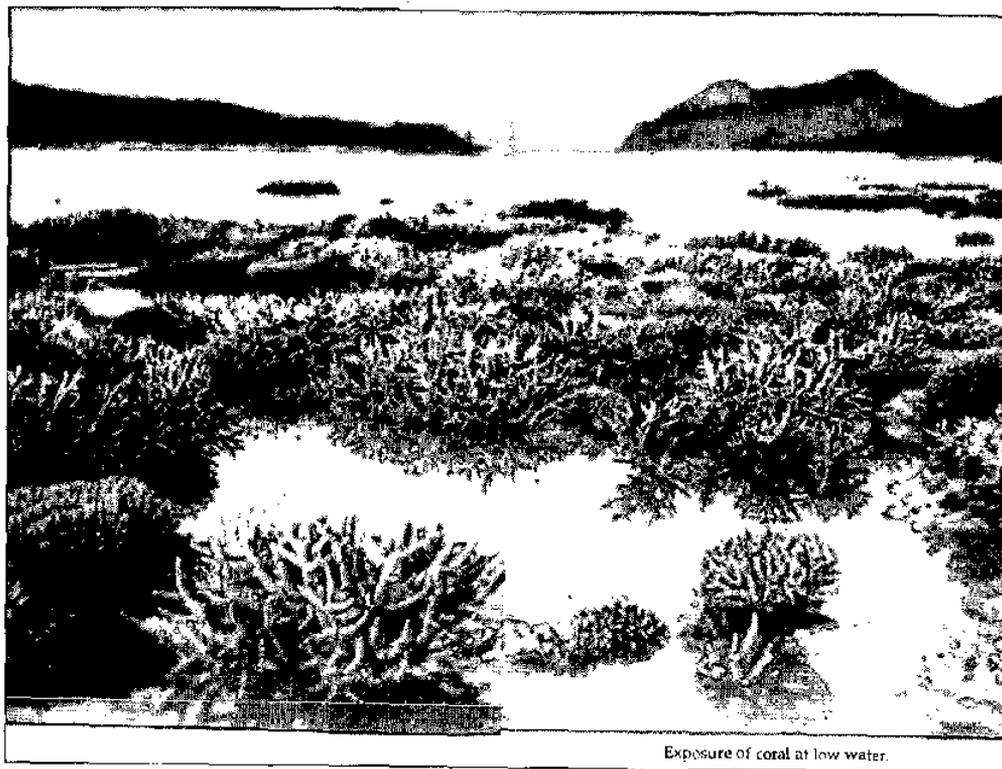


Figure 1. Map showing positions of locations for which historical photographs were found



**Figure 2.** Reef-flat at Daydream Island pre-1950 (top; photographer unknown) and 1995 (bottom; Andrew Elliott)

### Stone Island

Nine historical photographs from Stone Island were found. Six of these photographs have distinctive landmarks on the horizon, the landmarks are too distant to allow exact relocation of the original sites. Thus, the modern versions of these historical photographs must be considered as general comparisons, rather than specific ones. The other three historical photographs do not show any landmarks on the horizon, therefore, only general comparisons with the modern reef-flat are possible. Despite the inability to relocate the sites of the historical photographs exactly, comparisons are still valid because the modern reef-flat is very homogeneous, with movements of several hundred metres making little difference to the appearance of the reef-flat. All nine of the historical photographs were taken prior to 1915 and show extensive hard coral cover including many colonies of plating, corymbose and caespitose *Acropora* and many massive coral colonies. Today, the reef-flat has no colonies of *Acropora* exposed at spring low tide and few massive coral colonies. The surface of the reef-flat is now covered in a mixture of coral rubble and algae. Fig. 3 shows one of the typical historical photographs and its modern equivalent.

A cyclone in 1918 destroyed the Stone Island reef entirely (Hedley 1925; Rainford 1925). However, although no photographic evidence has yet been discovered, local residents say that between 20 and 30 years ago, there was a healthy reef-flat at Stone Island.

### Magnetic Island

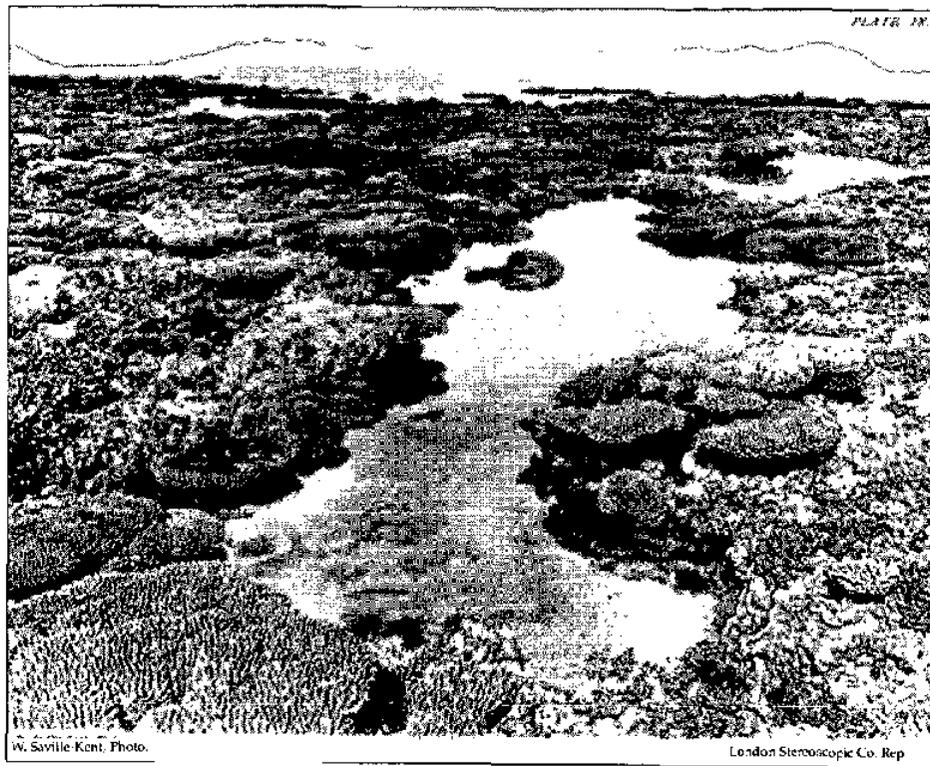
Endean (1976) presented a photograph of the reef-flat at Geoffrey Bay taken in 1952. The photograph shows high cover of branching hard coral, although the quality of the photograph is too poor to distinguish any detail. Endean also presented another photograph, supposedly of the same area, taken in 1971 that shows no living coral at all. Endean used the two photographs to illustrate the 'destruction of the bulk of coral colonies that formerly flourished on the island's fringing reefs'. However, examination of the photographs indicates that the 1971 photograph was taken much further from the seaward edge of the reef-flat than the 1952 photograph.

Geoffrey Bay was visited in 1995 in order to document the current benthos of the reef-flat. A variety of different benthic communities in different areas of the Bay were found.

Near the southern end of the Bay, two large areas of caespitose *Acropora* (30-50 m long and approximately 10 m wide) were found near the seaward edge of the reef-flat. Photographs of these areas closely resemble the 1952 photograph presented by Endean. Thus comparison of the modern reef with this historical photograph provides no evidence of change. However, these areas of *Acropora* represent a very small percentage of the total area of the Geoffrey Bay reef-flat. It is not possible to tell from the historical photograph whether or not this was also the case in 1952.

The majority of the seaward edge of the reef-flat of Geoffrey Bay was dominated by coral rubble covered in a variety of algae. Most of the reef-flat away from the seaward edge was of a similar substratum and closely resembled the benthos of the 1971 photograph presented by Endean (1976).

In the centre of the Bay, within approximately 15 m of the beach, there was an extensive area where the benthos was comprised of *Montipora digitata* and *Halimedu* sp.



**Figure 3.** Reef-flat at Stone Island circa 1890 (top; William Saville-Kent) and 1994 (bottom; Andrew Elliott)

In addition to the two photographs from Endean (1976) four other historical photographs of Magnetic Island were found, all taken in 1952. However, it is uncertain whether these were taken in Geoffrey Bay or Nelly Bay and all four photographs show only reef-flat substratum, with no landmarks, therefore it is not possible to relocate them. However, it is worth noting that all benthic organisms depicted in these photographs (including foliaceous *Montipora*, *Lobophyton* soft coral and branching *Acropora*) can still be found on the Geoffrey Bay reef-flat.

Thus, overall, comparison of the modern Geoffrey Bay reef-flat with available historical photographs provides no evidence of change.

#### Great Palm Island

Eight historical photographs of Coolgarce Bay, Great Palm Island were found. All eight were taken by William Saville-Kent circa 1890. In all eight historical photographs, the landmarks are relatively close to the site of the photograph, allowing accurate relocation. These sites, together with those at Orpheus Island, are probably the most accurately relocated sites in the project, with the exception of Hayman Island. The relatively large number of historical photographs from this location and the relatively high accuracy with which they were relocated make this one of the best studied locations in the project.

The historical photographs show a reef-flat consisting mainly of colonies of massive corals (*Goniastrea*, other faviids, *Porites*) and soft corals (probably *Sinularia* spp.). The modern photographs show a similar reef-flat.

#### Orpheus Island

Eight historical photographs of this location were found. All eight were taken by William Saville-Kent in Little Pioneer Bay circa 1890. As with Great Palm Island, the proximity of the landmarks at this location allowed accurate relocation of the sites of the historical photographs. This, coupled with the relatively high number of photographs makes Orpheus Island and Great Palm Island the best studied locations in the Project.

The historical photographs show a reef-flat very similar to that at Great Palm Island and the modern photographs show little, if any, change.

#### Fantome Island

One historical photograph of this location from circa 1890 was found, however, there was insufficient time during the Palm Islands field work to take a new photograph. However, the reef-flat was observed as the tide was rising and it was similar to the reef-flat of 100 years ago. The benthic community is similar to those at Great Palm Island and Orpheus Island, being dominated by a mixture of soft corals and massive hard corals (mostly faviids). Although this location is considered as one with no evidence of change, this conclusion is weaker than for Great Palm Island and Orpheus Island because there is only one historical photograph from Fantome Island.

#### Fitzroy Island

One historical photograph of Fitzroy Island from around 1910 has been found. This shows a high cover of various growth forms of branching *Acropora* and scattered colonies of massive corals. This reef was badly affected by cyclone Joy at the end of 1990. When visited in 1995, all the coral growth forms visible in the historical photograph were observed, but the cover was

much lower. Soft corals were also seen on the reef, although they are not depicted in the historical photograph. The majority of the substrate on the reef-flat was coral rubble and soft coral. As this reef-flat continues to develop after cyclone Joy it will be interesting to document whether the benthic community returns to that depicted in the historical photograph or not.

#### Green Island

Of the twelve historical photographs from Green Island that have been found, six are of particular interest.

Two of these historical photographs were taken on the reef-flat to the north-east of the island. One of these was taken circa 1958 and shows many large colonies of branching *Acropora*. The second was taken circa 1963 and shows large areas of soft corals, with no colonies of *Acropora* visible in the photograph. Today, the dominant organisms on this area of the reef-flat are soft corals, with the modern reef-flat appearing identical to the circa 1963 photograph. A small number of mostly very small (< 20 cm diameter) colonies of *Acropora* are present.

The four remaining historical photographs were taken at the far south-eastern edge of the reef pre-1968. The photographs depict a diverse benthic fauna comprised of soft corals, several different growth forms of *Acropora* and tridacnid clams. Because of the nature of the landmarks in the photographs, it was not possible to relocate the site of these photographs exactly. However, large areas of this section of Green Island reef were found to have very similar benthic fauna when the area was revisited.

Thus, although there is evidence of change from the north-east of the island, there is no such evidence from the south-east. This observation of spatial differences is confounded by temporal differences because the photographs from the south-east are probably more recent than those from the north-east.

#### Double Island

Two historical photographs from Double Island have been replicated. One photograph from 1970 shows colonies of branching *Acropora*. Similar patches of coral are common on this area of the reef-flat today, despite a thick layer of mud covering much of the reef-flat. However, the second historical photograph, taken further south along the edge of the same reef-flat shows an area completely covered in alcyoniid soft corals. Unfortunately, the date of this photograph has not been determined yet. When visited in 1995 no part of this area of reef-flat was dominated by alcyoniid soft corals. Occasional, solitary adult colonies and several dense patches of small (about 2 cm diameter) alcyoniid colonies were the only soft corals observed. This represents the only case of an observed decrease in soft coral cover during the course of the project.

#### Michaelmas Reef

Three historical photographs of this location were found. All three were taken on the same day in the mid-1950s. One of them appears on a postcard written in 1958, therefore the photographs must have been taken prior to this year. During the field work at Michaelmas Reef, it was possible to determine that the sites of the historical photographs were on the reef-flat to the south of the cay, however, the weather was poor and it was not possible to see the landmarks. In the third photograph, the only landmark is a sand spit that was presumably part of the cay. Because the sand around a coral cay is so mobile, the sand spit does not provide a landmark that can be used to relocate the site of the historical photograph. Therefore, the exact sites of the three historical photographs could not be located. However, a series of general photographs of the reef-flat to the south of the cay were taken. The historical photographs show assemblages

including branching hard corals and soft corals in approximately equal proportions. The modern reef-flat has almost no hard coral of any description and is dominated by alcyoniid soft corals.

The evidence from the historical photographs suggests that there has been significant change on the reef-flat at Michaelmas Cay.

#### Low Isles

Twelve historical photographs of Low Isles have been found, all taken during the scientific expedition of 1928-29. However nine of these are of relatively little use because they show only elevated banks of coral rubble, reef-flat from a great distance or are too indistinct. Of the three best photographs, one was taken on the seaward edge of the reef-flat to the south of the cay, one was taken in the middle of the reef-flat to the south of the cay and one was taken on the seaward edge of the reef-flat to the north-east of the cay.

The historical photograph from the seaward edge of the reef-flat to the south of the cay shows a dense and uniform cover of branching hard coral. When this area was revisited in 1995, a 10-15 m wide band of similar coral was found along approximately 500 m of this edge of the reef-flat.

The historical photograph from the middle of the reef-flat to the south of the cay shows large, submerged colonies of *Porites* sp. Colonies of this type were also found during the field work in 1995. The reef-flat to the south of the cay was qualitatively described in great detail by Stephenson et al. (1931). The modern reef-flat benthos in this area still contains all the elements described in 1931, including hard corals (e.g. *Acropora* spp., *Montipora digitata*, *Porites* sp.), sea cucumbers (mainly *Holothuria atra*), horses foot clams (*Hippopus hippopus*), seagrasses and sand.

The final historical photograph is from the reef-flat to the north-east of the cay and shows a high cover of *Acropora* spp. of different growth forms. No soft coral is visible in the historical photograph. Although this historical photograph can only be relocated approximately due to a description of the area in the original publication, this area of reef is now dominated by alcyoniid soft corals, with the cover of *Acropora* spp. being much lower than depicted in the historical photograph. This observation is supported by the work of Bell and Elmetri (1995) who replicated a transect from the 1928-29 expedition on this area of reef-flat. Modern density of hard coral colonies was found to be only 4.9% of that recorded in 1928-29.

Thus the Low Isles reef shows mixed results, with some areas showing little/no change and at least one area showing a marked change in benthic community structure.

#### Pickersgill Reef

Three photographs from Pickersgill Reef, north of Port Douglas, taken in the late 1960s and early 1970s show diverse reef-flat communities of alcyoniid soft corals, robust growth forms of *Acropora* and smaller numbers of massive hard corals. When visited in 1995 this reef-flat showed large areas of almost identical benthic communities. Thus there is no evidence of change from the three historical photographs.

#### Discussion

Comparisons between historical and modern photographs can provide information that is useful in the management of the GBRWHA. Such comparisons can be used to distinguish between

reef-flats that should be of concern to managers and others that may require less attention. However, using comparisons between modern and historical photographs as a measure of reef-flat health is a coarse tool with several important limitations. These limitations must be considered when analysing photographic comparisons.

Firstly, historical photographs only show reef-flats. Irrespective of the degree of change observed on the reef-flat, conclusions about the state of any other part of the reef cannot be drawn. In addition, only photographs of reefs that are within sight of a significant landmark can be used in this project. Thus all reefs studied in this way will be close to the mainland, a continental island or a coral cay.

Clearly, a collection of historical photographs from a particular location does not represent results of a sampling design incorporating random sampling. Most photographers will have been attempting to illustrate a particular point when taking a photograph and it is impossible for us to know how representative any single photograph is of the whole reef-flat. This problem is worst when only one photograph from a reef-flat exists and is reduced when several photographs from one reef-flat at one time are available for study.

Photographs taken at an oblique angle to the substratum do not allow the substratum to be quantified easily. Without complicated geometric analysis of the photograph, the best that can be achieved is a qualitative, subjective impression of the substratum shown in the photograph.

Comparison of historical and modern photographs only provides two snap-shots of a continuous process of reef change. The comparison provides no information about the state of the reef-flat in the years between the two photographs. Thus, when comparing two apparently identical photographs of the same reef-flat that are separated by 100 years, it is not known whether or not the reef-flat has changed during that time period. It is equally possible that the reef-flat has remained unchanged over the last 100 years or that the reef-flat has changed but that in recent years it has returned to the state of 100 years ago. In addition, if comparison of modern and historical photographs does show a change in the reef-flat, this supplies no information as to the cause(s) of the observed change.

These problems of photographic comparisons should be considered when reading the accounts of individual locations.

From the results of this project, comparisons between historical photographs and modern observations of reef-flats can be made for 14 locations. These locations can be subdivided into three groups: locations at which

- no evidence of change was found (six locations),
- evidence of change was found at all sites (four locations),
- evidence of change was found at some sites, but not at others (four locations).

The locations in each of these groups are shown in Table 2 and Fig. 1. There is no consistent geographical pattern in which locations show evidence of change and which do not, e.g. inner shelf v. mid-shelf or north v. south. However, this observation is tentative due to the small number of locations involved.

In all but one case (one photograph from Double Island) where evidence of change was found, the change was a decrease in cover of branching hard coral and an increase in cover of alcyoniid soft coral and/or algae and/or coral rubble. No location showed a change involving an increase in the cover of hard coral. However, the significance of this observation must be considered carefully in light of the fact that the original photography is likely to have been

heavily biased in favour of hard corals because these make for more beautiful and spectacular photographs.

**Table 2.** Summary of evidence found for change/no change at each location

No change	Change	Mixture
Daydream Island	Stone Island	Hayman Island
Magnetic Island	Bramston Reef	Double Island
Great Palm Island	Fitzroy Island	Green Island
Fantome Island	Michaelmas Cay	Low Isles
Orpheus Island		
Pickersgill Reef		

Where evidence from historical photographs indicates that cover of living hard coral has decreased at a location, there is still no information about what caused this decrease. Potential causes of hard coral mortality on reef-flats that need to be considered include cyclones, predation by crown-of-thorns starfish (COTS), increased sediment load, increased nutrient load, freshwater from storms, reef-walking, anchor damage and climate change. Some of these factors are natural while others could be due to human activity. Unfortunately there is no way to tell from the photographs which factors have caused the observed changes.

The storms of 1918 caused massive mortality of reef-flat benthos over a wide area including reefs around Bowen (e.g. Stone Island and Bramston Reef), Daydream Island and Hayman Island (Rainford 1925). However, as early as 1925, differences in the degree of recovery between reefs were apparent, with Hayman Island reef-flat being markedly more advanced than others (Rainford 1925). Photographs from the 1940s from Daydream and Hayman Islands indicate renewed hard coral growth on the reef-flats and this growth, for the most part, is present today. It therefore seems unlikely that the current absence of hard corals from Stone Island and Bramston Reef reef-flats is due only to the storms of 1918.

Despite observed decreases in hard coral cover on some reefs, previous studies that have used historical photographs primarily or exclusively as evidence of hard coral mortality (e.g. Endean 1976; Bell and Elmetri 1995) are only seeing part of the picture. These studies have concentrated on sites of apparent reduction of hard coral cover at Stone Island, Magnetic Island and Low Isles. However, this trend is far from uniform when a larger number of reefs or a larger number of sites within a reef are examined. The Historical Photographs Project represents the most thorough and wide-ranging study of its kind to date but, even so, out of approximately 2900 reefs in the GBRWHA comparisons are available for only 14. Given the limitations of this technique, comparisons between historical photographs and modern reef-flats can never provide definitive, stand-alone proof one way or the other in the debate over whether or not the GBR is undergoing a steady decline. However, from the results of the Historical Photographs Project so far, the number of locations that do not appear to have changed since the historical photographs were taken throws doubt on the proposition that the GBR is subject to broad scale decline, whatever the proposed cause.

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