DISCUSSION

There was no evidence from the first two Norman Reef monitoring programs that the operation of the Great Adventures pontoon facility was causing any damage to coral communities. There had been some coral death beneath the pontoon due to shading and chain abrasion but tourist activities had had no discernible effect. The greatest effect recorded in these programs was the damage to corals in the control site and the semi-sub site caused by the wave action associated with cyclones Ivor and Joy in 1990 (Ayling and Ayling 1994a).

Going on previous experience (Ayling and Ayling 1994a, 1994b, 1994c, 1995), and assuming no other disturbance occurred, coral cover and coral height should have increased due to normal growth in the four years since the last survey in 1993. However, the northerly wind associated with cyclone Justin, that led to the break-off of the pontoon, caused significant natural damage to the coral community. In the control site, between 15-20% of coral colonies showed evidence of damage, compared with only 1-2% during the 1992-93 monitoring program. Coral height decreased slightly between 1993 and 1997, and overall coral cover decreased slightly in shallow water, and increased slightly in deep water, over the same period. These changes were due in both cases to changes in cover of the fast-growing, but fragile, acroporid corals. In shallow water the cyclonic waves had broken off part or all of many acroporid colonies, leading to a decrease in cover of around 20%, while poritids and faviids either increased slightly or remained stable. In deep water the rapid increase in acroporid cover evident between 1987 and 1993 had continued, in spite of the evidence of substantial damage to many of the colonies. This was primarily caused by the rapid spreading of the staghorn acroporids *Acropora microphthalma* and *A. youngei*. These spreading staghorn colonies had smothered some of the faviids and reduced cover of this group.

As well as the coral colony damage evident from our surveys there was substantial structural damage throughout the control site and in other areas of the reef. Many large colonies had been torn from the reef by the force of the waves, damaging part of the reef substratum and breaking other corals as they were rolled over the reef. Some large *Porites* heads had been turned over, and a few large bommies up to three metres in diameter had fallen on their side.

The break-off of the pontoon also caused the shifting and dragging of blocks and chains at the pontoon site. This should have increased damage in the vicinity of the pontoon compared to the control site. Despite the fact that a lot of obvious damage was observed at the pontoon site that was due to the pontoon break-off, the overall level of damage was equal or greater in the control site. In the shallow coral community, levels of coral colony damage were about 25% lower at the pontoon site than in the control site, colony height stayed approximately the same, rather than reducing as in the control site, and coral cover reduced by about the same level in both sites. The pattern was similar in the deep coral community, with significantly fewer damaged coral colonies at the pontoon site compared with the control site and a similar drop in coral height in both sites. There was, however, significantly higher coral cover in the deep control site compared with the pontoon site in 1997. This was due to continuing shading death of corals beneath the pontoon, especially of poritid corals, rather than to any pontoon break-off effects.

This supports the observation made previously (Ayling and Ayling 1994a) that many of the control site transects are more exposed to northerly wave action than those at the pontoon site, and hence more likely to suffer damage during a cyclonic episode.

While it is difficult to separate the low level of pontoon operation and tourist use damage from the substantial cyclone induced damage, there is no evidence that there was any noticeable damage at the pontoon site that may have been due to operations in the four years between May 1993 and the time of the cyclone. An exception to this is the already mentioned shading death of some poritid corals beneath the pontoon.

Although the dragging of the pontoon caused obvious structural damage to a small section of the reef flat community, it was surprising how much coral remained alive within the 2200 sq m drag scar. Although badly damaged, between a third and a half of corals were still alive at the time of this survey, almost four weeks after the cyclone. Most coral fragments had begun to repair themselves and it is expected that recovery of these acroporid dominated communities will be relatively rapid. The drag scar runs across the edge of the large patch of bright blue *Acropora nobilis* staghorn coral that we noted in 1987 (Ayling and Ayling 1989), and has badly damaged a section of this colony. However, most of the broken staghorn fingers were still alive and were showing evidence of repair and regrowth.

Management Implications

Two previous monitoring programs suggested that the Great Adventures Norman Reef pontoon was having very little detrimental effect on reef communities in the vicinity. Although almost a million people visited this site between 1987 and 1993 the only detectable effects were a slight but significant reduction in coral cover and coral height beneath the pontoon attributable to shading induced coral death and mooring chain abrasion. Tourist use of the area did not have a detrimental effect on coral communities in the vicinity of the pontoon; coral cover had actually increased markedly in the snorkelling area since the installation of the original pontoon due to natural coral growth. As far as it is possible to tell given the high level of cyclone damage, the results from the present 1997 survey suggest a similar story. Although pontoon shading had continued to reduce coral cover immediately beneath the pontoon, giving a 29% overall reduction over 10 years, there was no other evidence of damage due to pontoon operations.

The major effect on reef benthic communities in the area has been the northerly winds associated with two cyclones, Ivor in March 1990 and Justin in March 1997. Waves associated with Justin damaged 15-20% of coral colonies throughout the monitoring area and caused a reduction in coral height. There was also an overall nominal reduction in coral cover of 5.4% since 1993, and some reef structural damage.

Although the pontoon break-off caused some damage to reef communities in the vicinity of the pontoon site, this did not lead to an increase in damage at the pontoon site compared to the control site. The pontoon created a 240 m long drag scar across the reef flat of Norman Reef. To put this in perspective the scar affected an area that made up less than 0.1% of the reef flat of Norman Reef. The dragging pontoon only destroyed an area of approximately 320 sq m of living hard coral on the reef flat. This area is insignificant when it is considered that the cyclone probably destroyed a ball park estimate of 15 000 sq m of living coral along the back face of Norman Reef (this figure derives from aerial photos, which suggest there is about 30 ha of reef slope on this face, and assumes a conservative 5% coral cover reduction as measured between 1993 and 1997 in this study). The reef damage caused by the pontoon break-off episode was insignificant compared to that caused naturally by the cyclone.