METHODS

Coral Transects

Coral cover was surveyed along the same permanently marked 20 m long intersect line transects used for the 1987 and 1992 monitoring programs. These transects were positioned haphazardly and were marked by using 100 mm masonry nails driven into the coral substratum at approximately 2 m intervals along the transect line. Our experience has shown that masonry nails are inconspicuous but provide reliable marks that can be relocated over a period of at least five years.

The following organisms or groups of organisms were surveyed along the line intersect transects: all hard corals down to species level where possible but to structural groupings where reliable field identification is not possible, e.g. *Porites* spp. massive; total cover of fire corals (*Millepora* spp.); all soft corals to generic level where possible; total sponges; total area of substratum covered by turfing algae; total area covered by macroalgae. The intersect lengths in centimetres of all the above organisms with the transect line were recorded and converted to percentage cover measurements.

As we were interested in the possible effects of tourist activities, pontoon operations and cyclonic waves on fragile and branching type corals, measures of coral height were made along all the transects. Breakage of branching coral tips may not affect measurements of percentage cover significantly but can reduce coral height (Ayling and Ayling 1989). To quantify coral height the maximum height of living sections of branching and plate type corals was measured in a square metre centred on each metre of the transect line, giving 20 height measurements for each transect. For corymbose plate and tabulate type corals the 'height' was measured from the central stalk of the colony out to the widest part of the plate. If there was no erect hard coral within this square metre the colony nearest to the line outside this area was measured. The coral height for each transect was expressed as the mean of these 20 heights.

As an additional measure of coral damage, apart from the measures of colony height mentioned above, the number of damaged colonies in a 20 x 1 m strip centred on each line transect were counted along with the number of undamaged coral colonies in the same area so that the percentage of colonies damaged could be calculated. A colony was classed as damaged if any tips or edges were broken or if gouges and scrapes were present on the surface. Colonies less than 5 cm in diameter were excluded from these counts. Colonies over 50 cm in diameter were split into a number of nominal 'colonies' approximately 50 cm square and damage within each section recorded. This technique takes less than five minutes for each transect.

Sampling Design

The original 1987 design used four groups of five transects. In the vicinity of the pontoon there were five shallow transects to look at the effects of tourist snorkelling activities in front of the pontoon, and five transects in deeper water beneath the pontoon to look at the effect of shading and mooring chain abrasion. There were also five shallow control transects and five deep control transects set up about 100-200 m south of the pontoon.

In 1992 an additional four groups of five transects were set up. These included five new shallow snorkeller impact transects to cover more comprehensively the area used by pontoon visitors, five deep transects along the resort diver trail immediately in front of the pontoon, as well as five new shallow controls and five new deep controls about 100 m north of the pontoon site (figure 2).

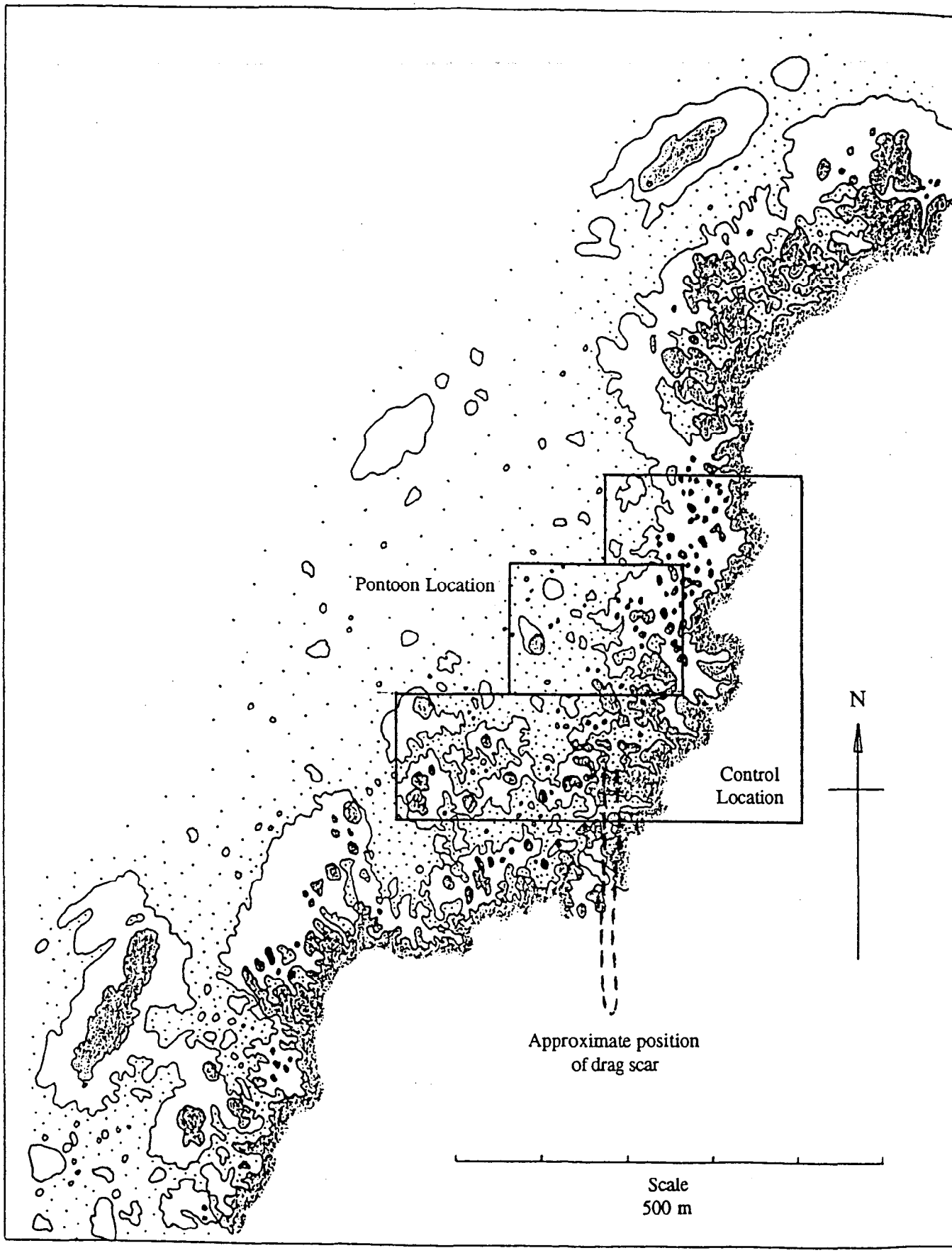

Figure 2. Norman Reef study area showing the position of the study locations

Table 1. Design of the coral survey component. Figures indicate number of transects.

Status	Impact			Control	
Potential impact	shading	fin damage		nil	nil
Year established	1987	1987	1992	1987	1992
Shallow		5x	5x	5x	5x
Deep	5x		5x	5x	5x

Drag Scar Damage

Because the benthic community on the reef flat changes with increasing distance from the reef edge, the scar survey was divided into three sections. Each section comprised about an 80 m length of scar and parts of the surrounding undamaged community on each side of the scar. Six haphazard 20 m line intersect transects were surveyed in each section, with three control transects surveyed on each side of the scar. The percentage of damaged coral colonies was measured along a 20 x 1 m strip in the same way as for the permanent transects, but coral height measurements were not made for these transects.

Timing of the Surveys

All 40 monitoring transects were re-located and re-surveyed between 18-22 April 1997. Although it was almost five years since the transects had been marked they were all located successfully using the detailed maps of distance and direction to each nail, and the type of coral or substratum that each nail was driven into. Although some nails had either fallen out, rusted away, or been overgrown by living corals, a minimum of four nails were re-located per transect, ensuring that the transects were located close to their original positions. All nails were replaced as near as possible to their former position. The drag scar surveys were carried out during the same period.

Analysis

Patterns in the cover of encrusting organisms for the line transects were tested using a repeated measures analysis of variance, suggested as appropriate for a design such as this by Kaly et al. (1993) (table 2). Separate analyses were made for the five time design that included the data from the previous two programs and the 1997 re-survey with five transects per location, and the three time design with 10 transects per location from the 1992-93 program and the 1997 survey, as well as for each depth strata. The term of most interest in these analyses was the time x location interaction. A significant interaction would result if coral cover was reduced at the impact location compared with the control by the activities associated with the pontoon, or by the pontoon breakaway.

Table 2. Coral cover survey analysis. Summarises the design for the four different repeated measures analyses of variance:
df 1 = 2 locations (impact, control); 5 times (87, 88, 92, 93, 97); 5 transects per location
df 2 = 2 locations; 2 times (92, 93); 10 transects per location

Source of variation	df 1	df 2	Denominator
Between Transects:			
Location	1	1	error (l)
error (l)	8	18	
Within Transects:			
Time	4	2	error (T)
T x L	4	2	error (T)
error (T)	32	36	