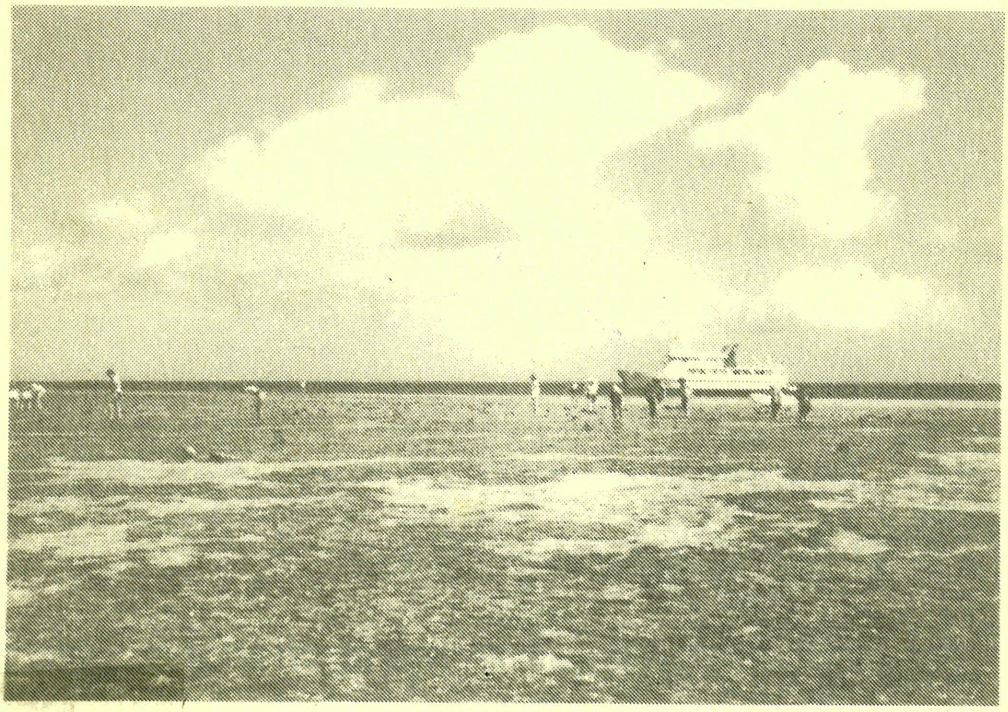
GBRMPA

THE IMPACT OF REEF WALKING AT HARDY REEF

1984 Report to
Great Barrier Reef Marine Park Authority

A.M.Kay and M.J.Liddle



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EXECUTIVE SUMMARY

Approximately one tenth of a square kilometre of reef flat is used for reef walking on Hardy Reef. This area is situated at the northern end of the reef and represents only a small proportion, less than 1%, of the total intertidal reef flat.

Tourists are transported to the reef via helicopter from Hamilton Island, amphibious aircraft from the mainland and the nearby Whit-Sunday Islands, and various cruise vessels. Between 30,000 and 40,000 reef walkers are estimated to visit the reef each year.

The coral communities in this area are mostly low and compact on a consolidated pavement of dead coral and are relatively resistant to trampling damage. One site within this area is characterized by more upright and delicate coral colonies and large sand pools and channels. There are no obvious signs of trampling damage on the reef except along the lagoon edge of the latter site where small boats run aground and reef walkers disembark.

More sponges and soft corals were found at Hardy Reef than at Heron Island Reef where the authors undertook a previous study of reef walking. However the morphologies displayed by the scleractinian corals and the types of substrates were similar at both sites.

A technique which was developed in the Heron Island study for surveying reefs in relation to the management of tourists was used in this study. The results indicate that it has very good potential as a simple and quick method for surveying reef walking areas in monitoring and assessment programs. The future development of this technique and the management of Hardy Reef is discussed.

THE IMPACT OF REEF WALKING AT HARDY REEF

1.0 INTRODUCTION

Reef walking is a popular holiday activity offered at most of the island tourist resorts along the Great Barrier Reef. Additionally it is listed on the itinerary of numerous cruise and tour operations based on the north east Queensland coast. In all cases it provides people with an opportunity to see and enjoy the unique reef environment first hand without the necessity of special physical skills. Visitors are transported or guided to selected coral reef sites at low tide where they are able to walk over the exposed reef flats and view the corals in their natural setting.

Research undertaken by Woodland and Hooper (1977) on Wistari Reef and by Kay and Liddle (1984) at Heron Island Reef at the southern end of the Great Barrier Reef (Fig. 1) has demonstrated that intertidal coral communities can be damaged by human trampling. In particular Kay and Liddle's (1984) field experiment showed that the severity and extent of the damage depends on both the level of use and the composition of the community.

Hardy Reef, located in the central Great Barrier Reef region near the WhitSunday Islands (Fig. 1 Plate 1), is another popular reef walking site and is visited regularly by a number of tour groups (Plate 2). The general aim of this report is to describe the reef walking activities on this reef with the following specific objectives.

1. To locate the major reef walking areas on Hardy Reef and estimate existing and possible future levels of use.
2. To describe the nature of these areas.
3. To assess the extent and nature of any damage resulting from the reef walking activities.

4. To evaluate a technique which was developed in the Heron Island study for surveying reefs in relation to the management of tourists.
5. To compare the nature of the reef walking sites at Hardy Reef and Heron Island Reef.

Figure 1. The location of Heron Island and Hardy Reef in the Great Barrier Reef.

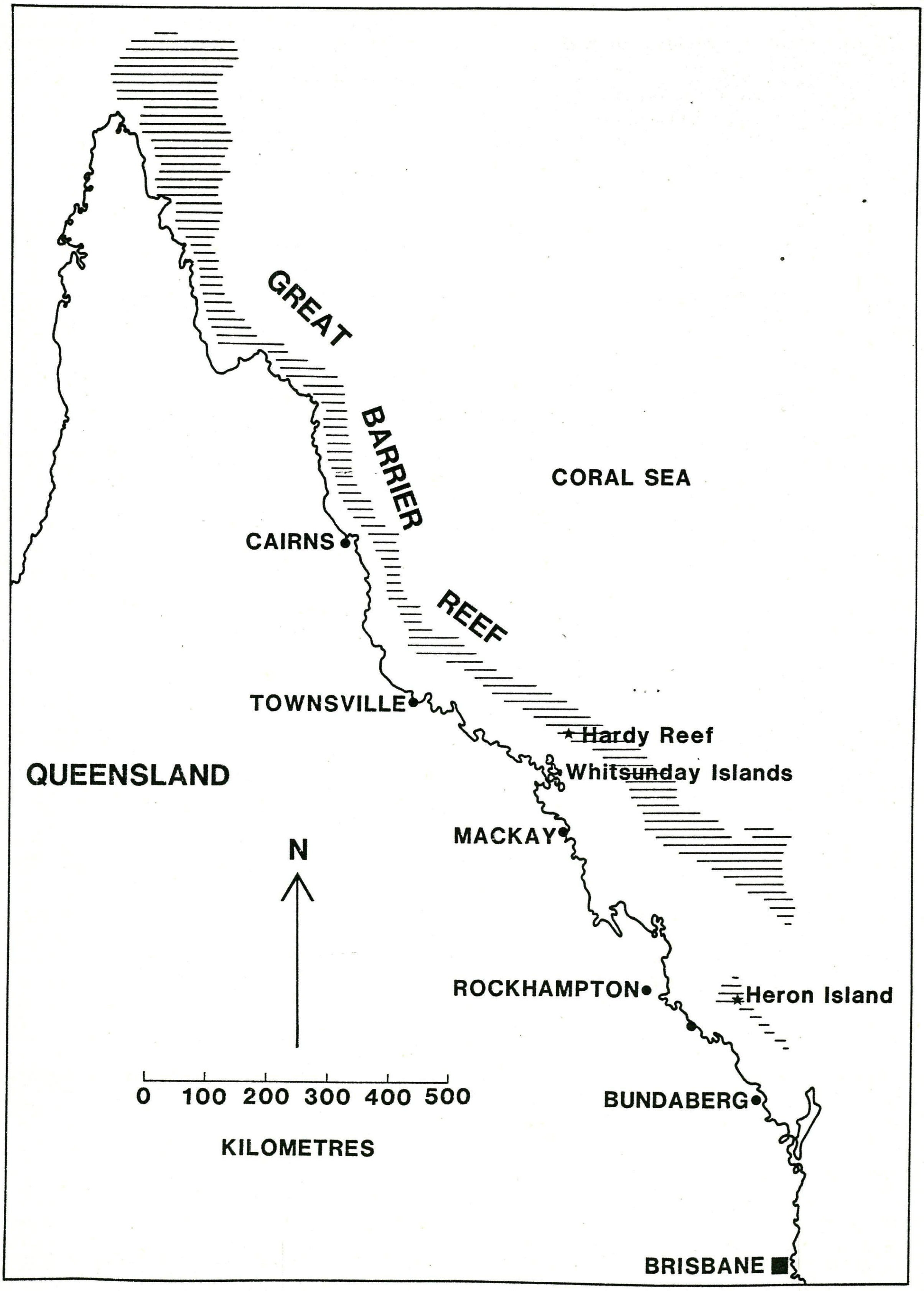
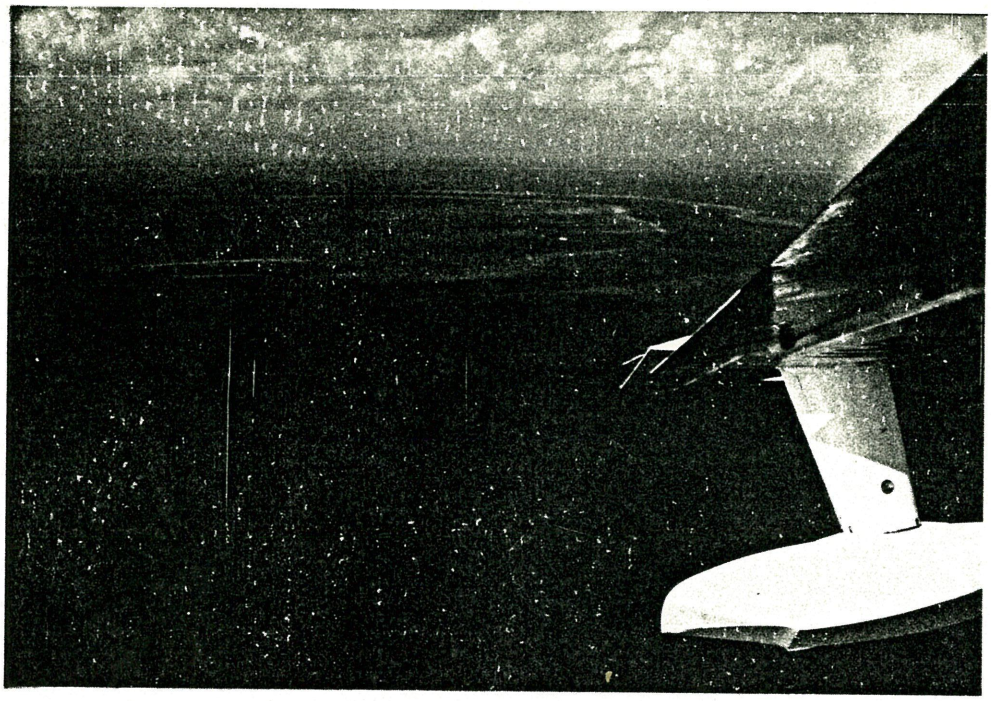
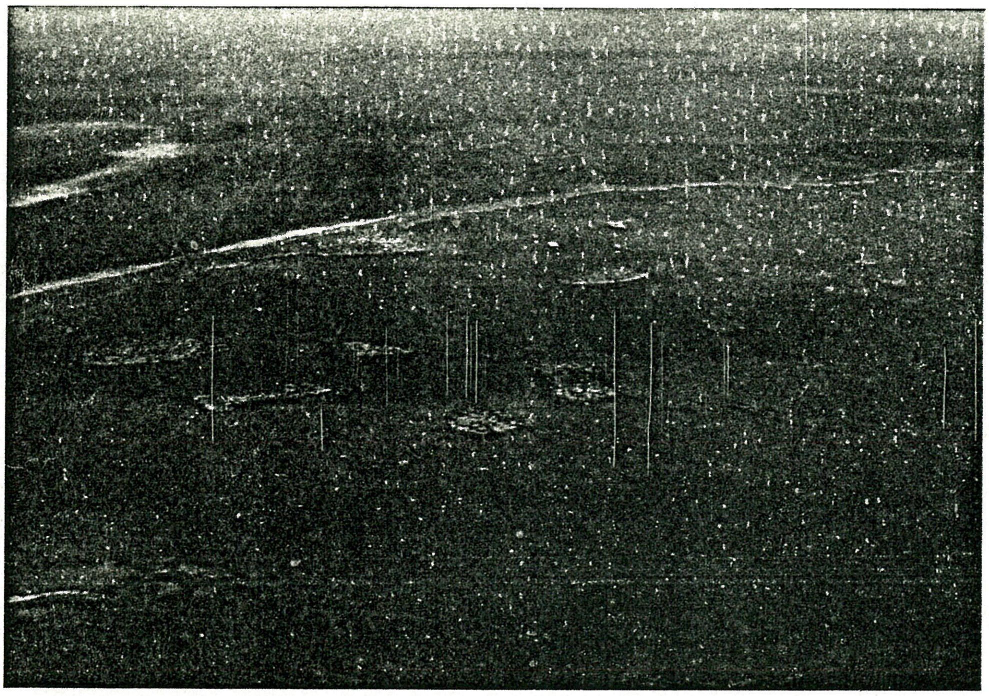


Plate 1 Hardy Reef





2.0 METHODS

2.1 Field Site and Field Trip Arrangements

Hardy Reef is a lagoonal platform reef (Maxwell 1968) with no sand cay (Fig. 2 Plate 1). Its reef flats are exposed once the tide drops below approximately 1.5 metres as measured at Mackay Outer Harbour. It is considered as a well known, accessible reef by local boat operators with a good anchorage at the northern end of the lagoon (Fig. 2).
The T.S.M.V."Roylen Sandra", a commercial accommodation vessel which is semi-permanently moored at the northern end of the Hardy Reef lagoon, was used as a field base. All field work was carried out between the 5th and 11th June 1984.

2.2 Survey Methods

2.2.1 General Reef Walking Areas

The areas used for reef walking were located by consultation with the reef walking guides employed by the Hamilton Island Tourist Resort and Air WhitSunday. These were then visually examined and three distinct sites (Fig. 3) were selected for quantitative description using the morphological classification scheme (Table 1) developed during the Heron Island study (Kay and Liddle 1984).
At each site six to eight transects about 100 paces long were positioned as shown in Fig. 3. The identity of each morphological or substrate category adjacent to the centre of the foot was recorded each step and percentage cover per transect was calculated from this data. All of these transects were recorded by Dr. Kay who had previous field experience with the morphological classification scheme.
At site 3 seven more transects were layed out (Fig. 3) and recorded by Dr. Liddle who had no previous field experience

with the morphological classification scheme. Before commencing his recordings Dr. Kay showed him different examples of the categories listed in Table 2 along another transect at this site. The data sheet Dr. Liddle used for the recording included simple drawings of each category as shown in Figure 4. These transects sampled the same community sampled by Dr. Kay and the two sets of data were later compared for significant differences. The aim of this procedure was to determine if the classification scheme could be used by inexperienced personnel to produce an accurate description of the community.

An additional two transects, one recorded by each author, were located about 100 metres from site 3, five to seven metres from the lagoon edge of the reef flat (Fig. 3).

2.2.2 Damage Assessment at Site 2

At site 2 three one metre wide transects were layed out in the positions shown in Figure 5. The transect located along the lagoon edge of the reef flat where reef walkers disembarked from small boats and that on the reef flat were 30 metres long. The transect located on an unvisited portion of the lagoon edge of the reef was 15 metres long.

Each transect was divided into metre long quadrats containing an evenly spaced grid of 20 points as depicted in Figure 5. The identity of the morphological or substrate categories falling under each of these points was recorded and the percentage cover per square meter was calculated from this data.

In addition the percentage cover of detached fragments of live coral were estimated by eye in 30 meter square quadrats on the reef flat transect and 10 one meter square quadrats along the boat landing site and unvisited edge transect. These fragments were then counted, collected and weighed on the "Roylen Sandra".

2.2.3 Statistics

The data produced in this survey was not normally distributed and non-parametric statistics (siegel 1956) were used for analysis.

Figure 2. Hardy Reef showing reef walking areas at the north end.

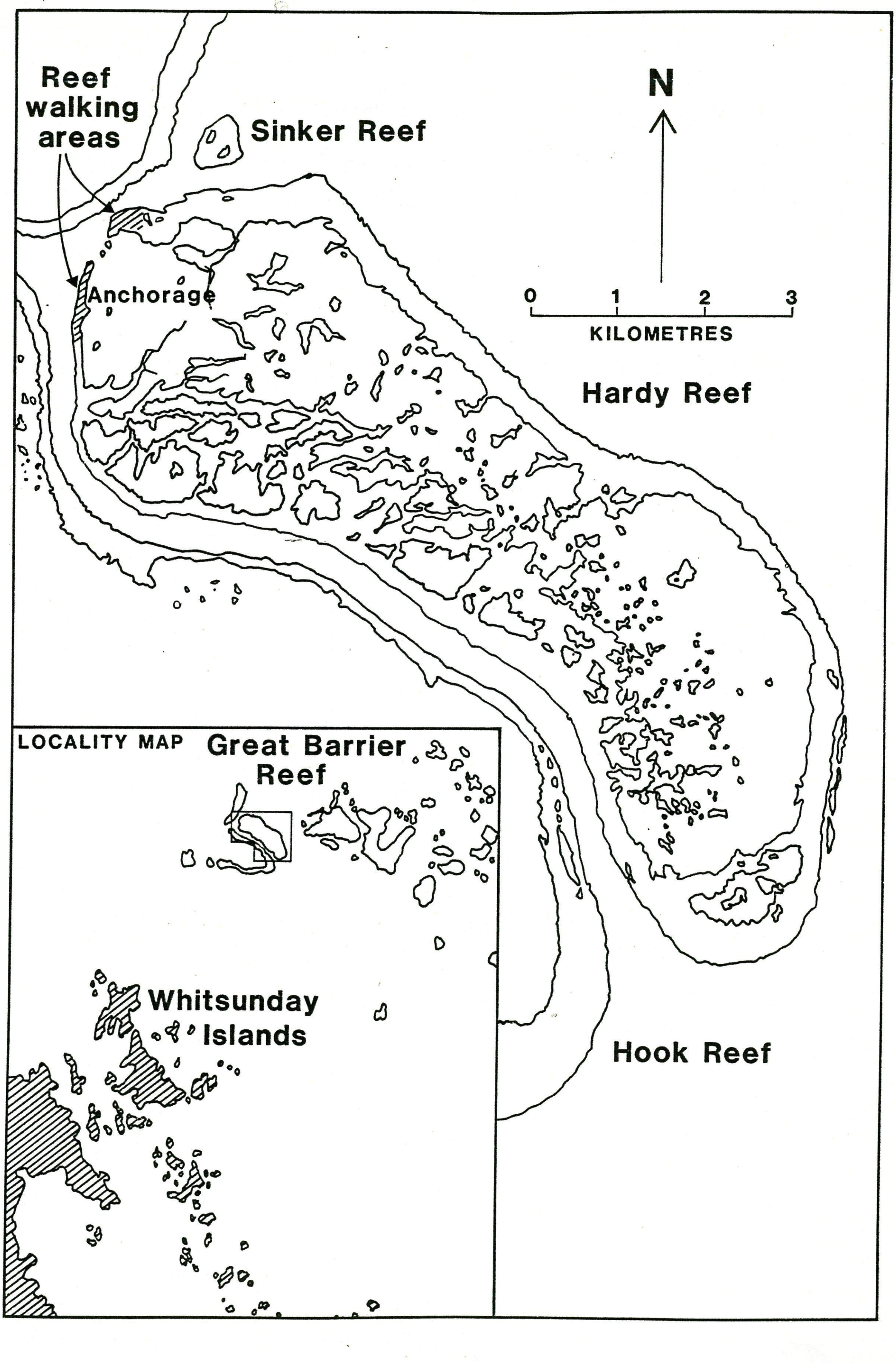
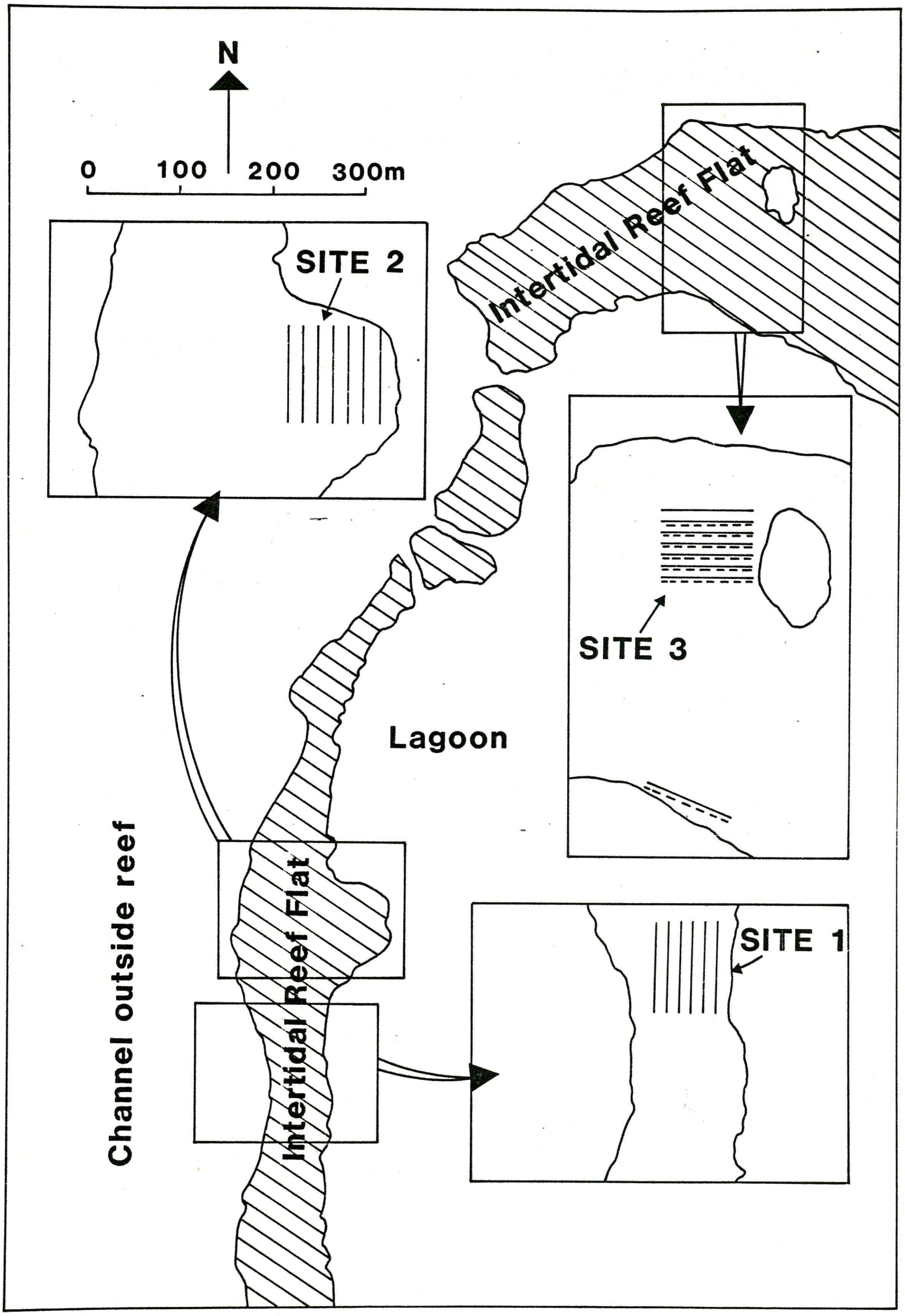


Figure 3. The location of the 3 survey sites and the paced transects.
Dr. Kay — Dr. Liddle - - - -



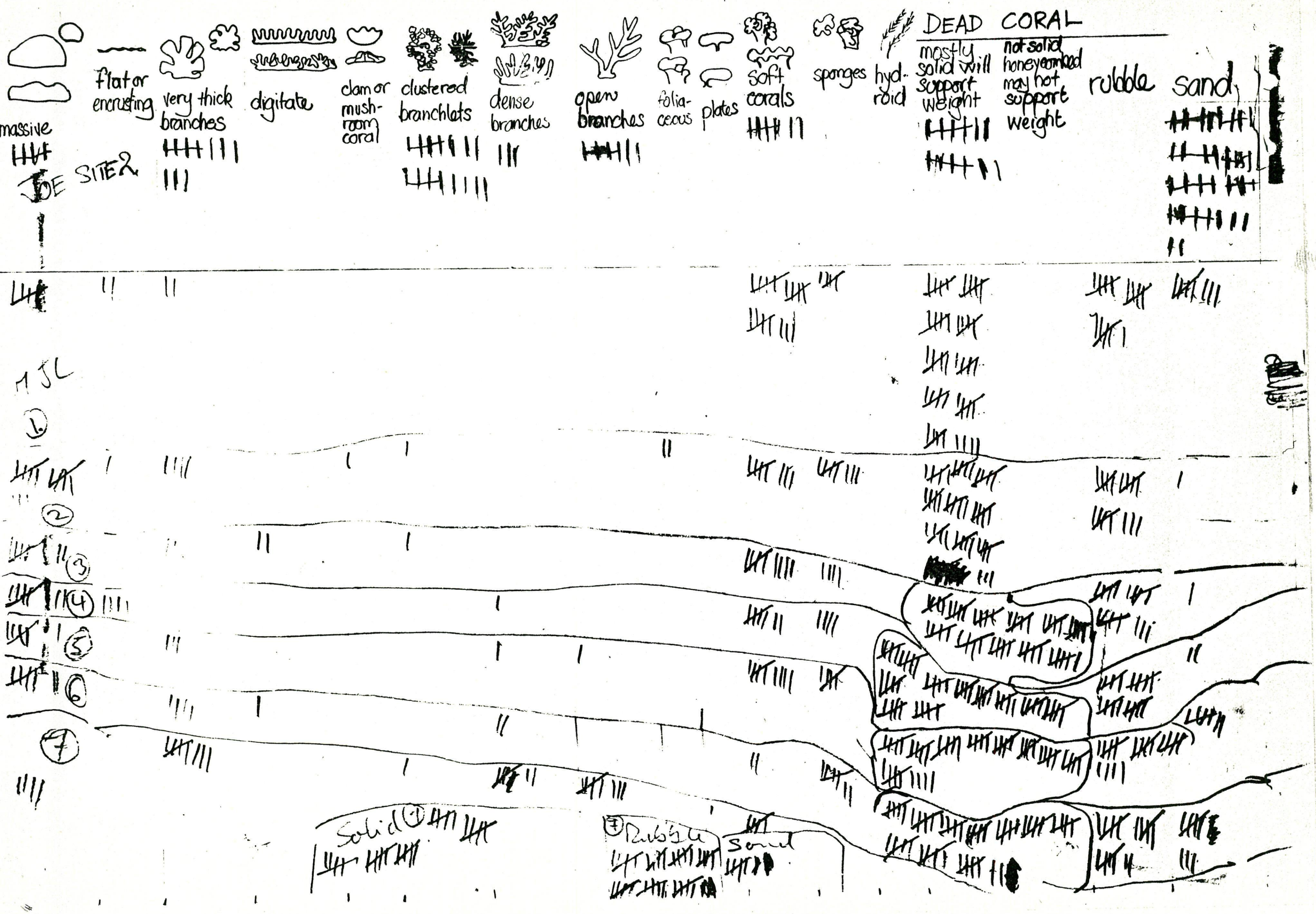


Figure 4. The data sheet used by Dr. Liddle.

Figure 5. a. The meter wide transects located at site 2.

b. The positions of the 20 points within the metre square quadrat.

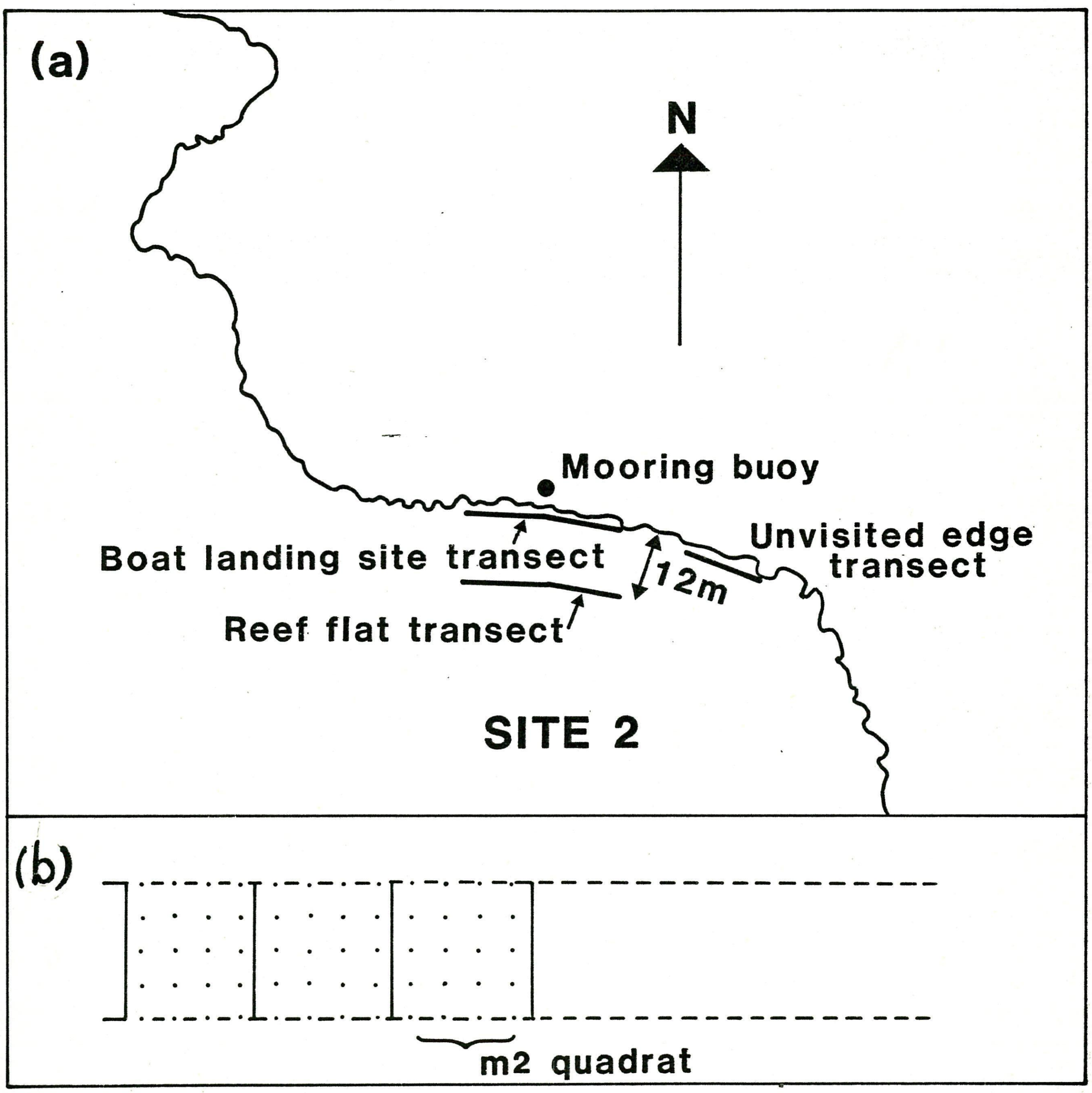
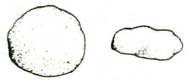
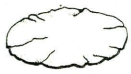
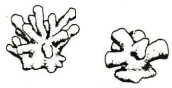
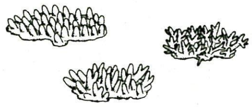
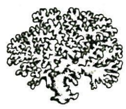
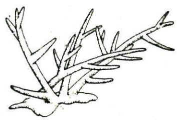
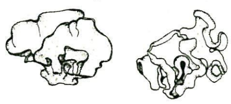
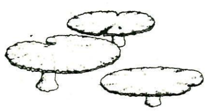


Table 1. The classification scheme for coral morphologies, sessile invertebrates and substrates. Modified from Kay and Liddle 1984.

Morphological categories	Typical colonies	Susceptibility to trampling damage
massive		very low
encrusting		
wedge, blade like or thick knotty branches		
digitate to low corymbose or caespitose		
solitary		
clustered branchlets		
high corymbose or caespitose		
open arborescent		
foliacious		
plate		very high

Other categories	
soft corals	not known
sponges	not known
hydroids	not known
consolidated coral pavement	not damaged
unconsolidated dead coral {colonies or stands of coral skeletons not, or partially, cemented together by coralline algae}	broken up by trampling
sand	not damaged
rubble	sometimes reduced to smaller fragments

3.0 RESULTS

3.1 Reef Walking Areas and Levels of Use

On Hardy Reef reef walking is confined to the northern end of the reef as shown in Figures 2 and 3. Table 2 lists the major sources of reef walking groups in this area and an estimate of the frequency of visits and the number of people per visit. This data was provided by the skipper, Mr A. Southwood, of the T.S.M.V. Roylen Sandra which has been semi-permanently moored at the site for the past year. It was consistent with information provided by the reef walking guides from Hamilton Island and Air WhitSunday.

From these figures we calculate that around 31,000 reef walkers would visit this area, approximately 100,000 square metres of reef flat in one year, however precise information on the density of walkers for a given time period within the area is unavailable. Nevertheless, the following general patterns could be determined by observations during the field trip and anecdotal information provided by the reef walking guides.

At the time of writing only the Elizabeth EII is using Site 3 whilst the other operators are using the area to the south of the break in the reef (Fig. 2). All the cruise boats, with the exception of the Roylen Sandra, remain outside the reef during visits and people are transported to the reef edge via smaller

vessels (Fig. 6). These are usually driven up onto the outer reef crest which is still partly submerged at low tide.
The groups from Hamilton Island arrive by helicopter and are usually transported from the landing pontoon by glass bottom boat to the lagoon side of site 2 (Figs. 5,6).
During the field trip this pattern had temporarily been altered to the one used below by the Air WhitSunday operation.
Visitors flying Air WhitSunday or staying on the Sandra were usually transported to site 1, or just south of it in a small boat and disembarked on the lagoon side of the reef (Fig. 6).
In general reef walkers did not wander more than 100 metres from their landing points and kept in loose groups associated with the reef walking guide (Plate 2.).

3.2 Nature of the Reef Walking Areas

3.2.1 Subjective Assessment

Visual survey suggested that most of the reef walking area contained low compact coral communities where the less vulnerable colony morphologies predominated (see Table 1. for a description of these). Most of the inert substrata was consolidated coral pavement typical of reef crest zones (Bennett 1971). Exceptions to this occured near the lagoon edge of the reef adjacent to site 3 and at site 2. In these cases there were more arborescent corals and the colonies were higher than in the other areas. There was also less consolidated pavement. Subjective impressions also indicated that sponges and soft corals were present throughout the reef walking areas.

The three sites chosen for the transect surveys were known to be regularly used by reef walkers. Sites 1 and 3 were chosen as typical examples of the low compact community type and site 2 represented the more upright community type. The two extra transects near site 2 also traversed this type of community.

3.2.2 Transect Surveys

The data in Figure 7 supports the visual impressions above. Consolidated pavement represents over 80% of the inert substrate at both sites 1 and 3 and the coral morphologies that are most vulnerable to trampling damage (high corymbose or caespitose, open arborescent, plates and foliaceous forms) are in very low abundances. In comparison open arborescent colonies are much more abundant at site 2 and consolidated pavement is less abundant. Sand is the most abundant type of inert substrate at this site. The percentage cover of open arborescent colonies is also relatively high on the two extra transects near site 3 (Fig. 8).

Sponges and soft corals together occupied at least 8% of the substrate at each of the three sites and in the case of site 3 they made up approximately half of the living community. Hydroids were also recorded at sites 1 and 2.

3.3. Comparison with Heron Island

Figure 7 also shows the structure of the reef flat and crest communities which were used in Kay and Liddle's (1984) long term trampling experiment at Heron Island Reef.

Sponges and soft corals were more abundant at all of the Hardy Reef sites than the two Heron Island sites (Figs. 7,8) and hydroids were not recorded at the two latter sites. Sites 1 and 3 at Hardy Reef resemble the Heron Island reef crest sites in that most of the substrate is consolidated pavement and the corals which are most vulnerable to trampling damage are rare.

However there is a marked difference, whereas most corals on the Heron Island crest have a digitate to low corymbose to caespitose morphology they do not dominate either Hardy Reef site (Fig. 7a, c).

Site 2 resembles the reef flat at Heron Island in that corals with knotty to wedge shaped branches and open arborsecent morphology are common and that consolidated coral makes up less than 20% of the inert substrate (Figs. 7b). However the composition of the inert substrate differs between the two sites. Excluding sand, unconsolidated coral makes up 90% of the remaining inert substrates at Heron Island whereas it makes up less than half at Hardy Reef. Figure 7b also suggests that sand was much more abundant at Hardy Reef, however, this may be an artifact of a difference in transect layout between the two sites. On the Heron Island reef flat the sample transects were layed out to avoid sand pools where possible.

3.4 Comparison of Recorders at Site 3

The percentage cover data collected by Dr. Kay and Dr. Liddle did not differ significantly for any morphological or substrate category with the exception of unconsolidated pavement (Table 3 Figure 7c). Dr Kay's estimates (1.5 ± 1.23%) were significantly higher than Dr. Liddle's (0.0 ± 0.0%). Discussion indicated that we had classified the intermediate forms of substrate between the two extremes of completely solid and thickets of branching coral skeleton differently.

3.5 Damage Assessment at Site 2

On site impressions and visual appraisal of Figure 9 suggested that open arborescent corals were in greater abundance along the reef flat and unvisited edge transects than the boat landing site transect (Fig. 9). However this difference was only significant between the reef flat transect and boat landing transect (Table 4).

The abundances of inert substrate also appeared to differ between transects (Fig. 9). Consolidated pavement was most abundant on the edge transects while sand was most abundant on the reef flat transect (Fig. 9 Table 4). This was consistant with casual observations which indicated that the sand pools petered out and were replaced by solid substrate in the last two or three metres before the reef dropped off fairly sharply into the lagoon.

The percentage cover of mobile rubble was greatest along the boat landing site transect and was statistically equal along the other two transects (Fig. 9 Table 4). In comparison the percentage cover of unconsolidated coral was smallest along the boat landing site transect (Fig. 9) although pairwise comparisons showed that this difference was only significant in relation to the reef flat transect (Table 4). These results were also consistent with initial impressions that mobile rubble was most abundant, and unconsolidated substrate least abundant, in the area were the boats landed and reef walkers disembarked.

The percentage cover, number and weight of detached live fragments of coral was clearly greatest along the boat landing site transect and this difference was very highly significant (Figure 10 Table 5). These fragments were quite obvious on casual inspection of this site and were conspicuously rare or absent elsewhere.

Plate 2. Reef Walkers on Hardy Reef.

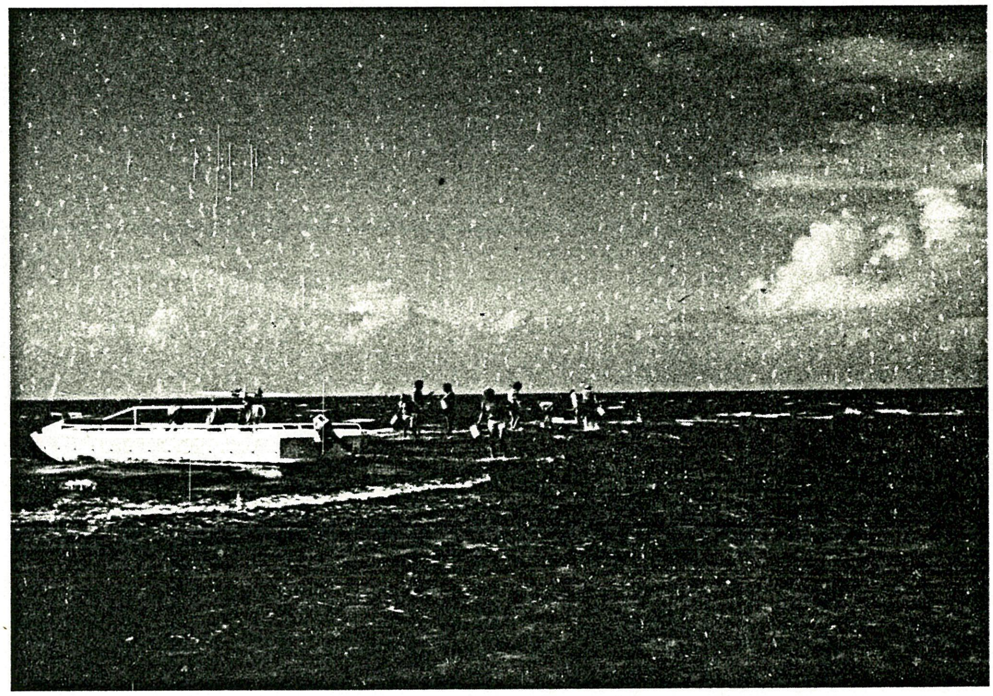


Table 2. The sources and numbers of reef walkers visiting Hardy Reef. The figures are estimates provided by A. Southwood who operates the T.S.M.V. "Roylen Sandra".

Craft and Operator		Frequency of visits	Average Number of people per visit
Triton II ex Airlie Beach	J. Smith P.O. Box 150 Airlie Beach	3 per week	40
Elizabeth EII ex Mackay	J.& R. Evetts 102 Goldsmith St, Mackay	1 per week	28
Telford Capricorn ex South Molle Island	Telford South Molle Island Tourist Resort	3 per week	100
T.S.M.V. 'Roylen Sandra' - Reef Encounter	A.& B. Southwood P.O. Box 56 Airlie Beach	moored at North end of lagoon	6 persons a day
Launch from Hayman Island Tourist Resort		1 per month	100
Amphibious aircraft ex Airlie Beach Hayman Island	Air WhitSunday Airlie Beach	7 per week	25
Helicopter ex Hamilton Island	Hamilton Island Resort	5 per week	6

Table 3. Results of Mann Whitney U-tests comparing percentage cover data collected by Dr. Kay and Dr. Liddle at site 3. U is the test statistic, N1 = 7, N2 = 6, P = 2-tailed probability of a real difference.

* significant at the 5% level

Catagory	U	P
massive	10	.14
encrusting	19.5	.84
knotty wedge	13.5	>.29
digitate, low corymbose to caespitose	7.5	>.052, <.074
solitary	18.5	0.73
clustered branchlets	21	>.85
high corymbose to caespitose	10.5	>.14, <.18
open arborescent	21	1.0
foliaceous	17.5	>.62
plates	-	-
soft corals	17.5	>.62
sponges	14	.37
hydroids	-	-
consolidated pavement	21.5	1.0
not solid	6	.035*
rubble	9	.1
sand	13	.29
inert	16	.53
corals	17	.62
other	21	1.0

Table 4. Results of Mann Whitney U-tests comparing % cover data between the three transects at site 2. Z is the test statistic, p = 2-tailed probability of a real difference * significant at the 5% level, n = 30 for boat landing site and reef flat, n = 15 unvisited edge site

Comparison		Aborescent Corals	Rubble	Sand	Consolidated Pavement	Unconsolidated Pavement
Boat landing site vs unvisited edge site	Z	.08	2.59	1.01	.38	1.54
	p	.94	.0096*	.31	.35	.12
Boat landing site vs reef flat site	Z	2.97	4.18	2.43	6.03	2.2
	p	.03*	<.00006*	.015*	<.00006*	.03*
unvisited edge site vs reef flat site	Z	1.72	1.07	4.12	5.06	.57
	p	.08	.28	<.00006*	<.00006*	.57

Table 5. Results of Mann Whitney U-tests comparing the live coral fragment data between transects at site 2. n = 30 for reef flat site, n = 15 for boat landing and unvisited edge site see caption Table 4 and 3 for further details.

Comparison		Weight gm. m^{-2}	% Cover	Numbers m^{-2}
Boat landing site vs unvisited edge site	U	5.5	6	6.5
	p	<.002*	<.002*	<.002*
Boat landing site vs. reef flat site.	Z	4.33	4.05	3.82
	p	<.00003*	<.00003*	.0011*
Unvisited edge site vs. reef flat site	Z	1.58	1.69	1.64
	p	.1142	.09	.10

Figure 6. Routes for transport of reef walkers from large boats or aircraft to the reef walking sites.

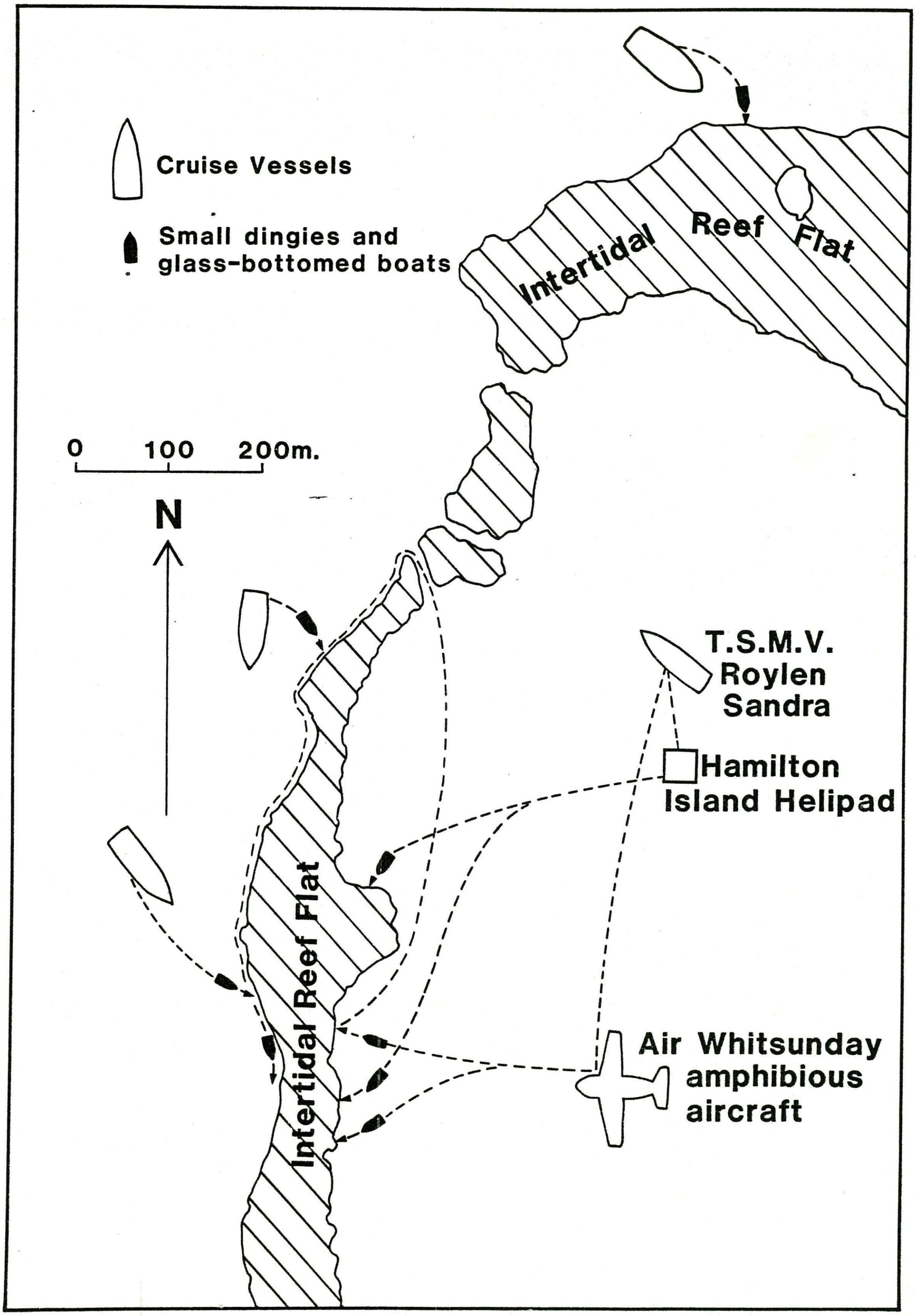


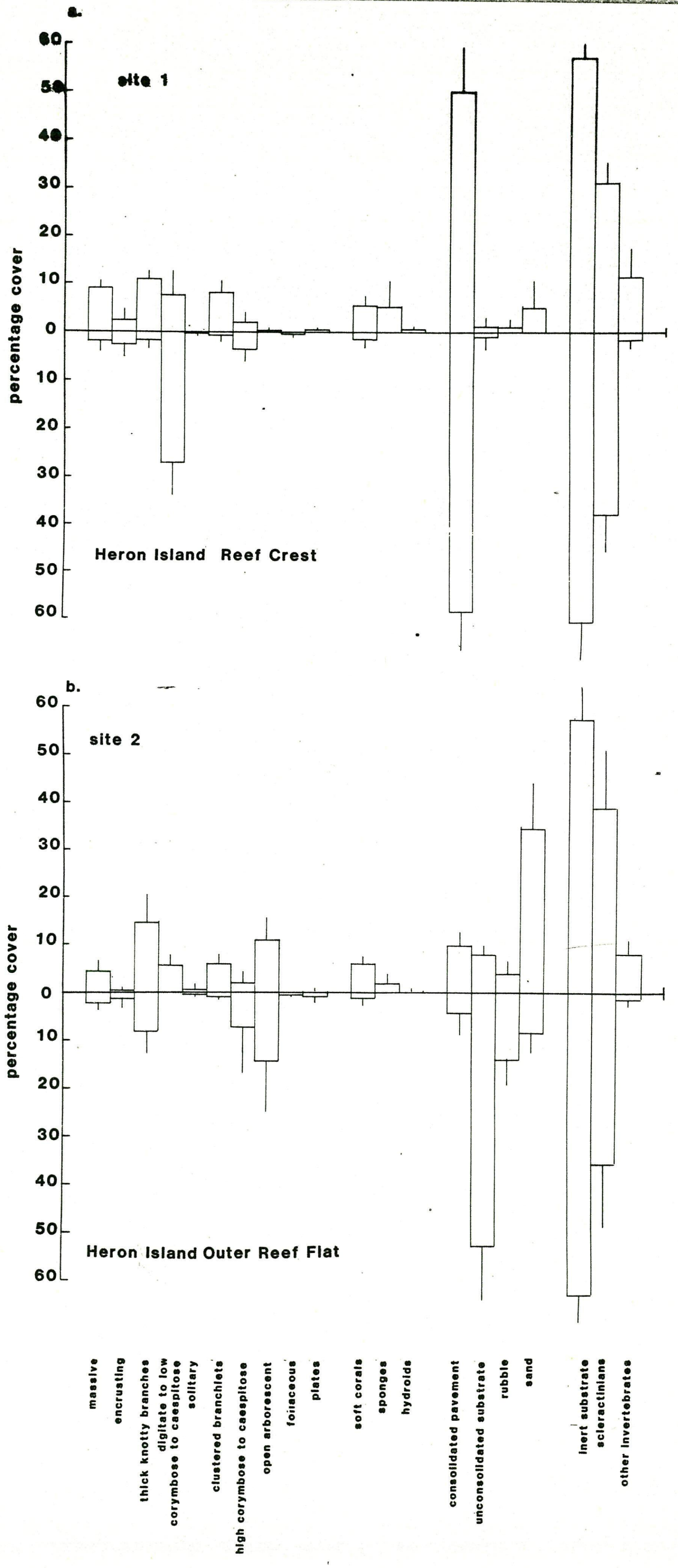
Figure 7. The mean and percentage cover for the different community components at

a. Hardy Reef Site 1 and Heron Island reef crest.

b. Hardy Reef Site 2 and Heron Island outer reef flat.

c. Hardy Reef Site 3 and Heron Island reef crest.

The heron Island data is calculated from 16 20 metre transects at each site in April 1982 using the line intercept method (Kay and Liddle 1984).


a.
site 1
percentage cover
Heron Island Reef Crest
b.
site 2
percentage cover
Heron Island Outer Reef Flat
massive
encrusting
thick knotty branches
digitate to low corymbose to caespitose
solitary
clustered branchlets
high corymbose to caespitose
open arborescent
foliaceous
plates
soft corals
sponges
hydroids
consolidated pavement
unconsolidated substrate
rubble
sand
inert substrate
scleractinians
other invertebrates

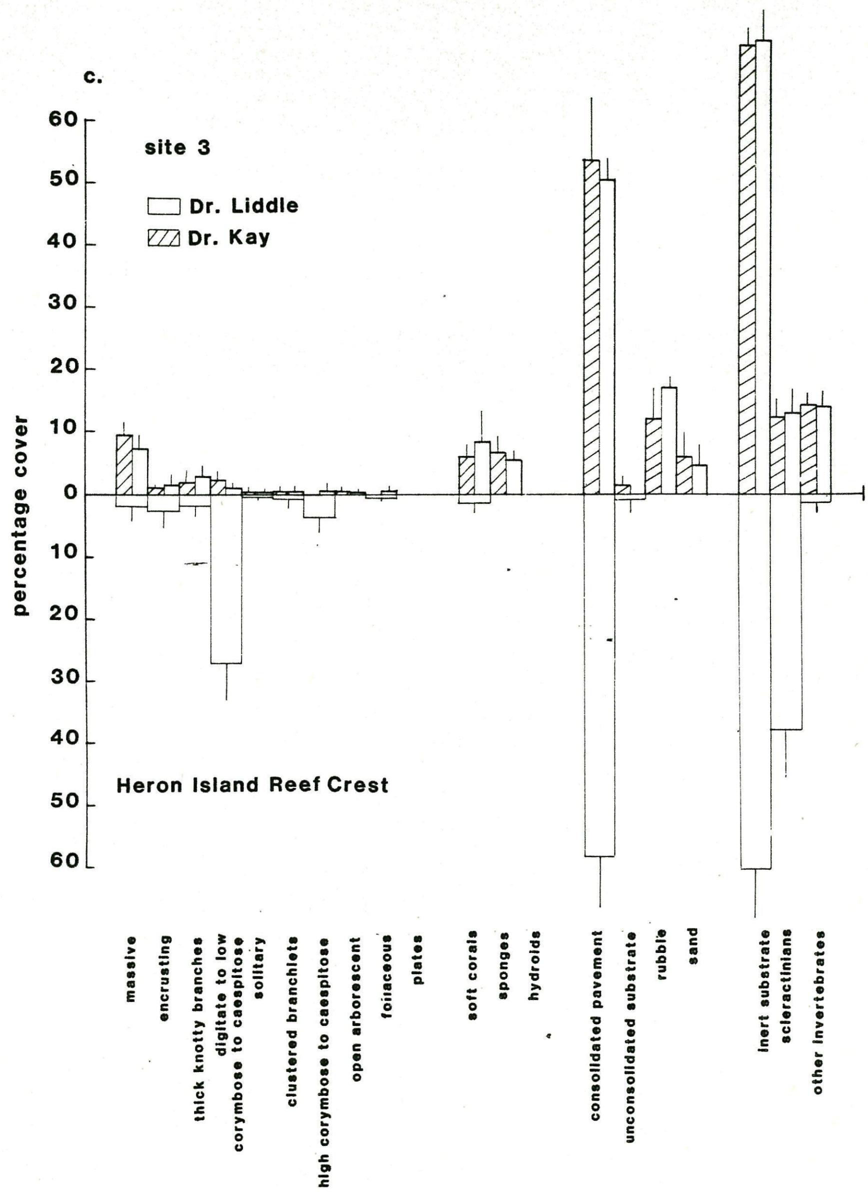

c.
site 3
Dr. Liddle
Dr. Kay
percentage cover
60
50
40
30
20
10
0
10
20
30
40
50
60
Heron Island Reef Crest
massive
encrusting
thick knotty branches
digitate to low
corymbose to caespitose
solitary
clustered branchlets
high corymbose to caespitose
open arborescent
foliaceous
plates
soft corals
sponges
hydroids
consolidated pavement
unconsolidated substrate
rubble
sand
inert substrate
scleractinians
other invertebrates

Figure 8. The percentage cover of different community components along the two extra transects near Site 3 on Hardy Reef.

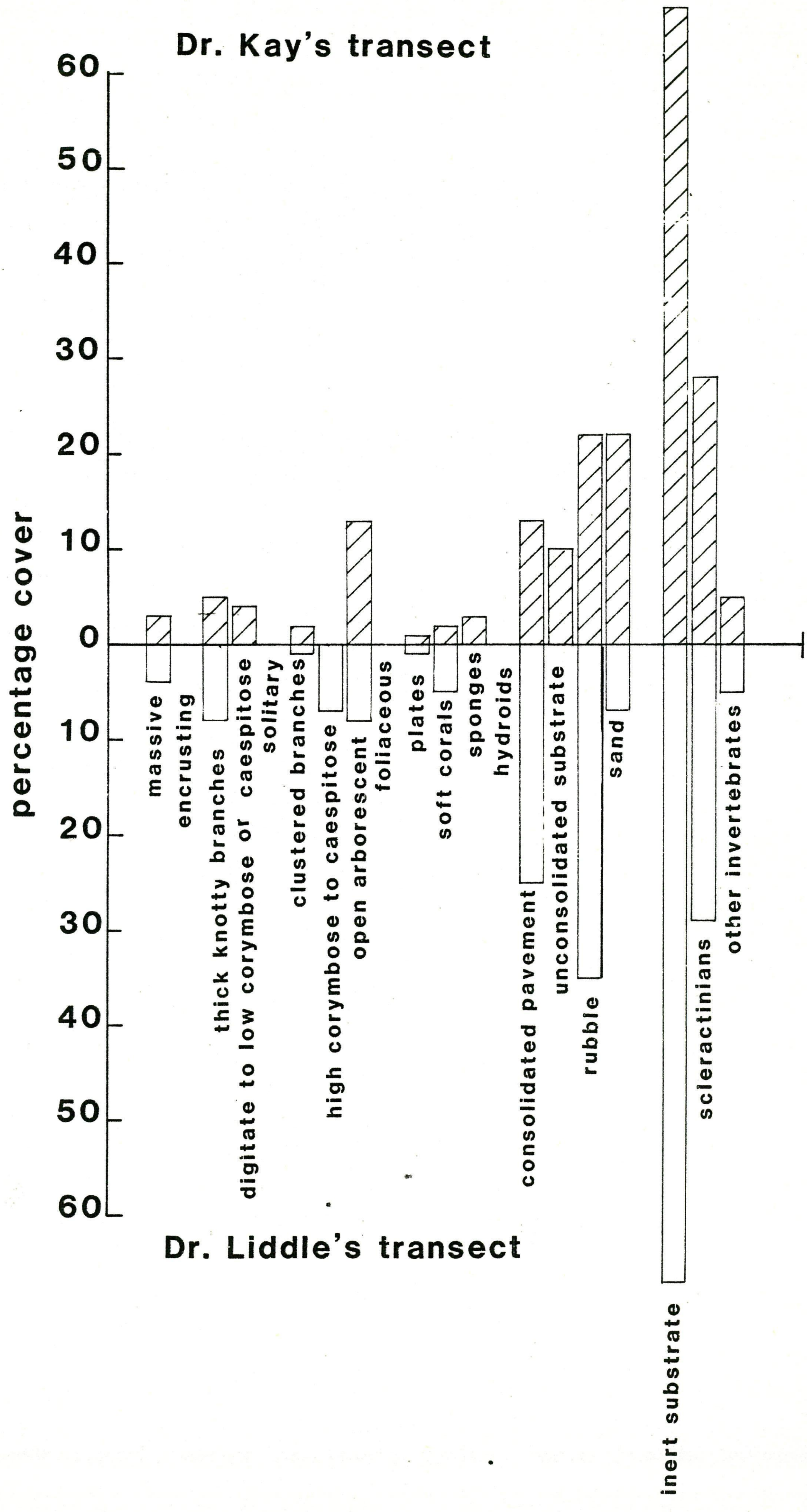


Figure 9. The mean and standard deviation of percentage cover for different community components along the metre wide transects at Site 2.

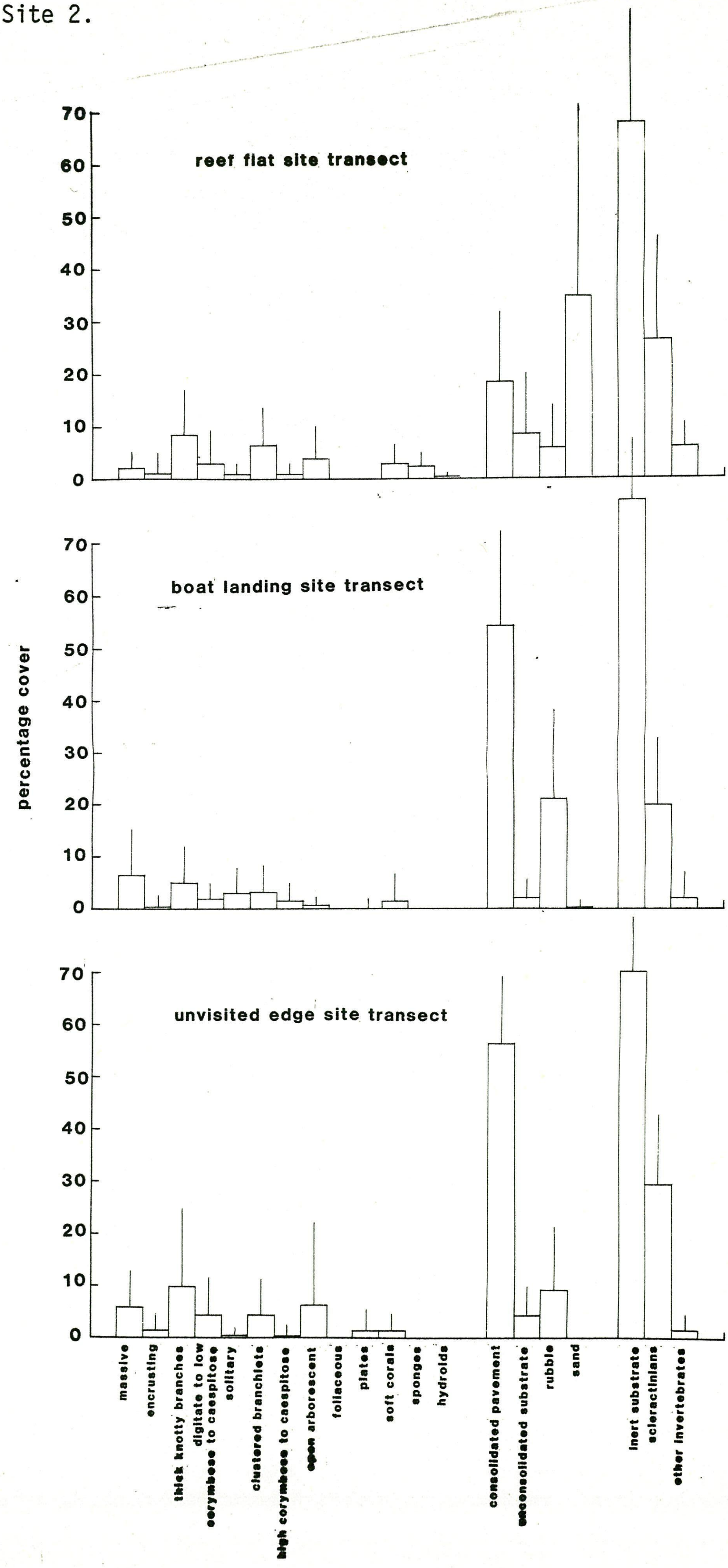
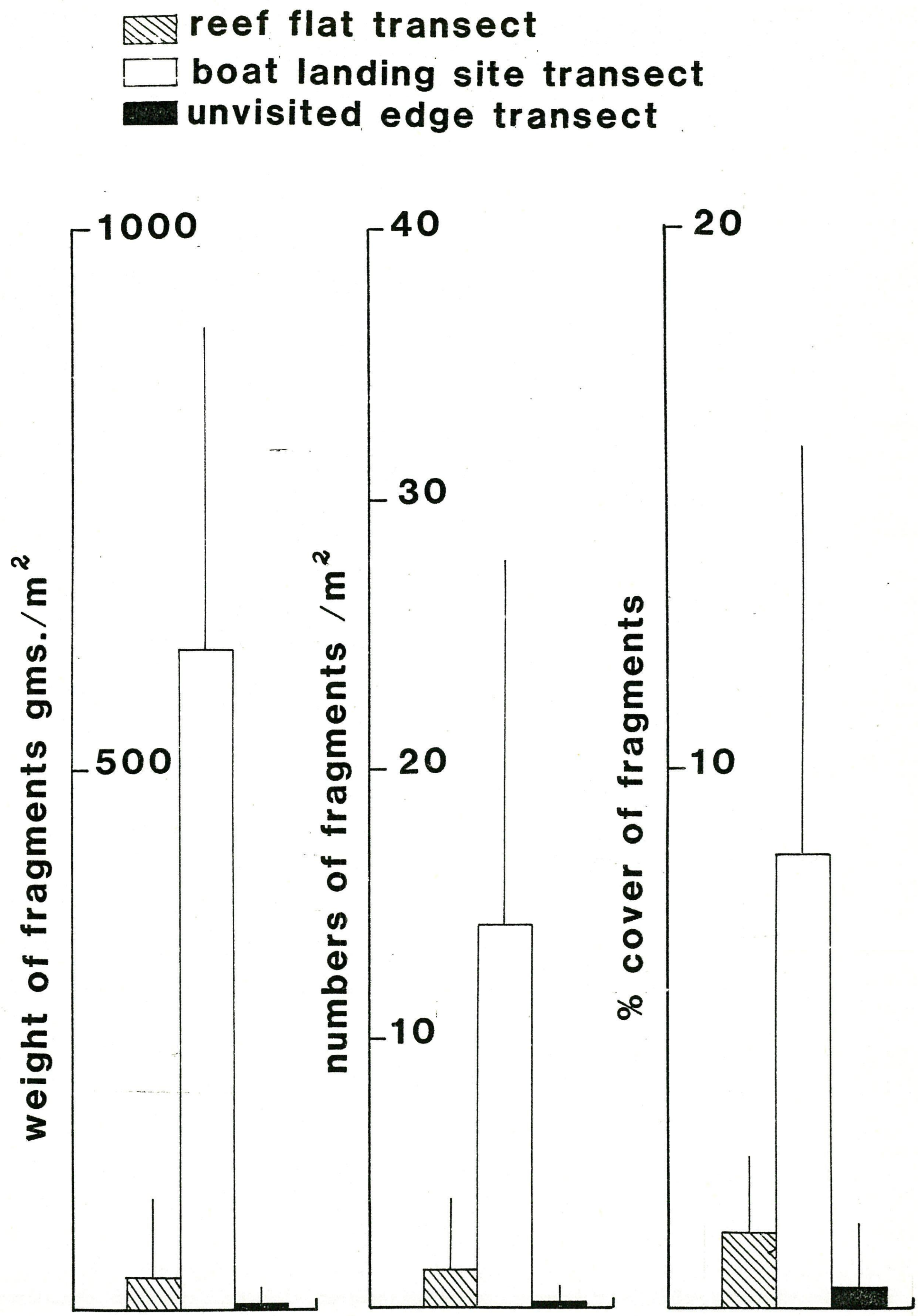


Figure 10. The mean and standard deviation of the weight, number and percentage cover of detached pieces of live coral fragments along the transects at Site 2.



4.0 DISCUSSION

4.1 Hardy Reef

4.1.1 Vulnerability to Trampling Damage and Present Levels of Damage

Most of the reef walking area at Hardy Reef resembles the reef crest site at the Heron Island which was used in Kay and Liddle's (1984) longterm trampling experiment. That area was shown to be relatively resistant to trampling damage and it follows that the areas at Hardy Reef will be similarly resistant provided the soft corals and sponges at the latter site do not prove to be very delicate. The lack of information about the susceptibility of these invertebrates to trampling damage is taken up later in the discussion. The remainder of the reef walking area, namely site 2, resembled the outer reef flat site in the Heron Island study which was very susceptible to trampling damage. However, site 2 contained large sand pools which reef walkers generally kept to avoiding the areas of live and dead coral. Thus, although this site contains a relatively high proportion of corals which would be easily destroyed by trampling it can tolerate high levels of use without damage providing people continue wading through the pools.

The only obvious signs of damage associated with reef walking were observed at the boat landing area at site 2. This area contained increased amounts of fragmented live and dead coral most likely due to the mechanical impact of boats grounding on the reef edge and the higher concentration, and awkward movements, of reef walkers at disembarkation points. This damage was, however, very localised and represented only a tiny fraction (< 1%) of the total reef walking area.

4.1.2 Future Use and Management

The present level of use at Hardy Reef is likely to increase provided that the tourist industry in Northern Queensland associated with the Great Barrier Reef continues to expand. Although the reef flat community at this site is relatively robust very intensive use in one locality would eventually degrade it. A long term monitoring program which recorded the composition of the reef walking sites at chosen intervals would allow detection of such changes. There are a variety of management procedures (see Kay and Liddle 1984) which could then be instigated to preserve the resource. As this present study indicates the edges of the reef flat are likely to show the effects of heavy use first due to the impact of large numbers of small boats. This type of damage could be localized simply by establishing fixed landing points known to the various operators.

The impact of the reef walkers on the reef flat could then be decreased in a number of ways. In situations where use was heavier than presently observed but not extreme coral walking leaflets encouraging people to walk only on robust substrates and avoid delicate corals could be circulated on the cruise boats and planes before disembarking. These leaflets could also contain information on what to see and thus serve the dual role of protecting the reef flat and describing some of its unique features as a natural community.

Alternative methods using artificial structures in the environment could also be used. Such things as elevated walkways, cleared paths between sand pools and sign posts would prevent or greatly decrease the impact on the delicate components of this community. However these procedures all involve visible alteration to a natural environment which is less desibable than a method which does not, provided the latter is equally effective. In situations of extremely heavy use, an order of magnitude greater than exists at Hardy Reef today, this is unlikely to be so and artificial structures may have to be used.

4.2 Evaluations of Survey Technique

The morphological classification scheme enabled us to describe the composition of the Hardy Reef reef walking areas in terms of the susceptibility of scleractinian corals and inert substrates to trampling damage. However it did not include sponges and soft corals in this assessment. To give this scheme broader applicability these sessile invertebrates need to be included in the trampling vulnerability hierarchy (see Table 1). Further experimental work is needed before this can be done with confidence.

Comparison of the survey data collected by Dr. Kay and Dr. Liddle indicated that the scheme can be used by personnel without a background in coral taxonomy or extensive field experience. However the difference in the authors estimation of unconsolidated substrate suggests that further refinement and field testing of definitions would be desirable.

The recording method used in this project was quick, did not require elaborate and cumbersome field equipment and produced quantitative data. In combination with the morphological classification scheme it represents a simple and effective survey technique for monitoring programs concerned with reef walking impacts.

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Table XXXI Concentration of Ni (mg l^{-1})

	SAMPLING PERIODS					
Sites	April	June	August	October	December	January
1	<0.018	0.034	<0.006	<0.006	<0.01	<0.01
2	<0.018	<0.018	<0.006	<0.006	<0.01	<0.01
3	<0.018	0.021	<0.006	<0.006	<0.01	<0.01
4	0.025	0.023	<0.006	<0.006	<0.01	<0.01
5	0.019	0.022	<0.006	<0.006	<0.01	<0.01
6	0.042	0.042	<0.006	<0.006	<0.01	<0.01
7	0.027	<0.018	<0.006	<0.006	<0.01	<0.01
8	<0.018	<0.018	<0.006	<0.006	<0.01	<0.01
9	0.25	<0.018	0.006	<0.006	<0.01	<0.01
10	0.034	0.022	0.006	<0.006	<0.01	<0.01

Table XXXII Concentration of Cr (mg l^{-1})

	SAMPLING PERIODS					
Sites	April	June	August	October	December	January
1	<0.01	<0.01	<0.037	<0.037	<0.01	<0.01
2	0.014	<0.01	<0.037	<0.037	<0.01	<0.01
3	<0.01	<0.01	<0.037	<0.037	<0.01	<0.01
4	<0.01	<0.01	<0.037	<0.037	<0.01	<0.01
5	<0.01	<0.01	<0.037	<0.037	<0.01	<0.01
6	0.01	<0.01	<0.037	<0.037	<0.01	<0.01
7	0.011	<0.01	<0.037	<0.037	<0.01	<0.01
8	<0.01	<0.01	<0.037	<0.037	<0.01	<0.01
9	<0.01	<0.01	0.037	<0.037	<0.01	<0.01
10	<0.01	<0.01	0.037	<0.037	<0.01	<0.01