APPENDIX 1: EXPERIMENTS ON CORAL TRANSPLANTATION AND ACCELERATED RECRUITMENT, MARCH 1985 TO SEPTEMBER 1986, GREEN ISLAND.

EXPERIMENT 1

AIMS

To measure collection effort and coral cover for 5 types of coral transplanted into marked quadrats.

DESIGN

Approximately 40 2 m x 2 m quadrats were marked with stakes and ropes in the backreef study site at Green Island Reef. This site was on the western edge of the reef and was gently sloping (depth at low tide 2.5-3 m), with a predominantly sand, rubble and calcareous algae (*Halimeda*) bottom.

The transplantation experiment was begun in May 1985 and incorporated seven treatments:

1. addition of fragments of colonies of pocilloporid corals, mainly *Pocillopora damicornis*, with some colonies of *Stylophora pistillata* and *Seriatopora hystrix*

2. addition of staghorn *Acropora* fragments, mainly of the open branching growth form, e.g. *A. formosa*, *A. grandis*, *A. florida*

3. addition of plate *Acropora* fragments including the species *A. hyacynthis*, *A. cytherea*

4. addition of branching *Porites* fragments (*P. cylindrica*)

5. addition of massive colonies (various taxa, mostly faviid species, but including a few massive *Porites*. Corals were of the genera *Favia*, *Favites*, *Platygyra*, *Leptastea*)

6. addition of settlement surfaces (dead coral surfaces)

7. controls (no additions)

Pocilloporid and branching *Porites* colonies were collected from Arlington Reef, and acroporid and massive colonies were collected from Middle Cay Reef. Corals were collected with a hammer and chisel and placed under the boat, with the collection time noted. Immediately before departure, the corals were loaded into filled water containers in the boat. The collecting trips involved a total travel time per trip of between 20 and 60 minutes depending on the sea conditions and the distance to the collecting site.

The number of person-hours devoted to collecting corals for a treatment was determined by a combination of the time available, the amount of deck space available on the boat, and how quickly that space was filled by the corals collected. Collection effort for each treatment is given in table 3. For the addition of settlement plates, effort was defined as the amount of time required to cut up the dead coral surface used.

Transplanted corals were placed into 4 or 5 quadrats, and the collection effort involved per quadrat for each treatment was measured. The different treatments were distributed randomly over the study site. As soon as possible after the transplantation date (after about 10 days because of very strong winds) 3 of the quadrats were mapped to enable an assessment of the number of transplants and approximate coral cover.

In July 1985 we mapped 4 quadrats for each treatment, including the corals that were present before transplantation.

In October 1985 all quadrats were remapped, and surviving coral cover calculated. We intended to extend observations over an 18-month period, but in February 1986 the passage of Cyclone Winifred close to Green Island resulted in the removal of virtually all transplants that had been established and so the experiment was terminated.

RESULTS

Table 3. Collection effort, number of transplants, and mean length of transplanted colonies following transplantation.

Treatment	Collection time (work-) hours	No. quadrats	No. trans-plants in 3 quads.	Fragments/ coll. hr/ quadrat	Colony length (x) (s.d.)
Massives	5	4	23	20	12.7 (4.9)
Pocilloporids	1.0	5	51	28	13.5 (6.2)
Acropora (plate)	0.5	4	32	28	15.4 (12.5)
Acropora (branch)	0.5	5	88	98	17.6 (approx.)
Porites (branch)	1.0	5	184	102	10.9 (approx.)

The branching colonies have the greatest number of transplants per collecting hour, but branching *Porites* fragments were relatively small. They also were difficult to distinguish from the rubble background after transplantation, and for this reason alone, they are unlikely to be suitable for transplantation to area where an aesthetically pleasing display is required.

Within a few months, the vast majority of the coral blocks added to the quadrats to provide settlement surfaces were buried by shifting sand. It was concluded that in this habitat type, added substrate would not accelerate recruitment.

The coral cover in the mapped quadrats 5 months after transplantation are presented in table 4.

Table 4. Coral cover and collection effort for four 2m x 2m quadrats, measured 5 months after transplantation. Results are presented only for coral fragments with a longest dimension greater than 10 cm, as survival of smaller pieces was found to be consistently low.

	Branch. *Porites*	*Pocillop.*	branching *Acrop.*	plate *Acrop.*	massive corals
No. pieces transplanted	112	44	72	24	28
No. pieces surviving	84	39	41	23	27
Surviving coral cover	26%	15%	23%	15%	8%
Collecting time	2.4	2.4	1.6	1.0	1.0
Surviving cover	11%	7%	16%	8%	4%

CONCLUSIONS

The highest survival rate of colonies or fragments was recorded for massive corals, plate *Acropora*, and pocilloporid corals. However the greatest cover per unit effort came from branching *Acropora*. These were easy to collect, occupied large amounts of space, and survival rate was acceptable.

Surviving cover of branching *Porites* was moderate, but the fragments blended with the background and would add little to the appearance of a reef area.

The experiment was prematurely terminated by the damage caused by Cyclone Winifred. As a result change in coral cover in control quadrats could not be determined. Changes over the first 6 months did not appear to be significant. The burial by sand of the coral blocks added to provide settlement surfaces for coral spat demonstrated the limited value of such a strategy in habitats with sandy substrata.

EXPERIMENT 2

AIMS

To further investigate survival of transplanted *Acropora* fragments with respect to fragment size and transport method.

DESIGN

Four branches from each of 9 colonies of branching *Acropora* were collected from Middle Cay Reef. There were 4 treatments:

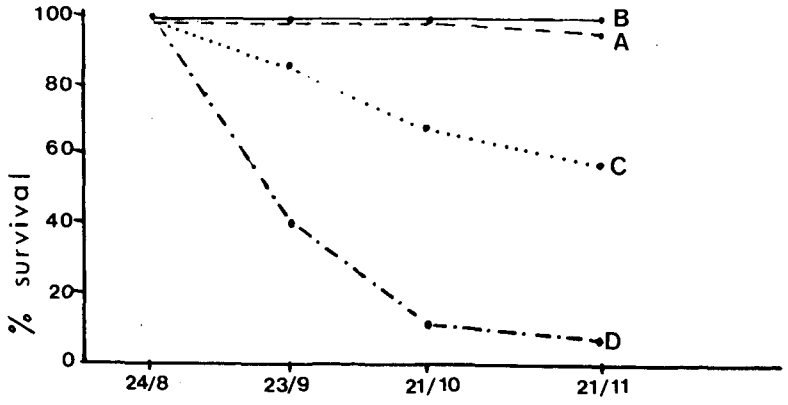
1. Branches >25 cm long were transported dry on the boat deck
2. Branches >25 cm long were transported in bins of water
3. Branches were broken into pieces 10 to 25 cm long, and transported in bins of water (38 pieces)
4. Branches were broken into pieces <10 cm long, and transported in bins of water (109 pieces)

Transport time was approximately 40 minutes. Corals were placed in the same backreef study site used in experiment 1.

RESULTS

Results are given in figure 8. There was no significant difference between survival of the corals carried on deck or in bins of water, over the next 3 months. There was decreasing survival rate for smaller fragments, such that survival over 3 months for fragments less than 10 cm long was less than 10%.

Figure 8. Survival of transplanted *Acropora* fragments (experiment 2). A=25cm long, dry on deck (n=9); B=>25cm long, submerged (n=9); C=10-25cm long, submerged (n=38); D=<10cm long, submerged (n=109).



CONCLUSIONS

Transportation of coral fragments exposed to air for short periods does not appear to increase transplant mortality, and mortality rate increases sharply with decreasing fragment size.

EXPERIMENT 3

AIMS

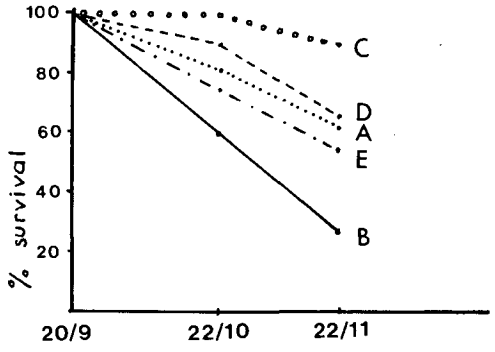
To examine differences in survival rate of branch and unbranched fragments of *Acropora*, and to compare survival rates at forereef and backreef sites.

DESIGN

On 19 and 20 September 1985, we collected 153 fragments of staghorn *Acropora* from Middle Cay Reef. Each fragment was 20 to 30 cm long and was either branched or relatively straight with few side branches. The fragments were carried in bins of water and travel time was approximately 50 minutes. Treatments were as follows:

1. 31 branched fragments placed in forereef site on rubble
2. 30 unbranched fragments placed in forereef site on rubble
3. 31 branched fragments placed in backreef site on rubble
4. 30 unbranched fragments placed in backreef site on rubble
5. 31 branched fragments placed in backreef site on sand

Figure 9. Differences in survival rate of *Acropora* fragments for branched and unbranched pieces and for a backreef and a forereef site (experiment 3). A=branched, forereef, rubble; B=unbranched, forereef, rubble; C=branched, backreef, rubble; D=unbranched, backreef, rubble; E=branched, backreef, sand.



RESULTS

Survival rates for the 2 months following transplantation are shown in figure 9. In both forereef and backreef sites, survival rate for unbranched fragments was less than for branched ones. In the backreef site, survival on sand was the lowest of all treatments, and large areas of surviving colonies were partially buried. The colonies seemed unlikely to survive for long periods. In this experiment, survival rate was higher in the backreef than the forereef site.

CONCLUSION

Survival rate was higher for branched over unbranched fragments, on rubble rather than sand, and in a backreef rather than forereef site.

EXPERIMENT 4

AIMS

To repeat the experiment testing the effect of fragment size on survival rate of *Acropora* fragments (i.e. experiment 2).

DESIGN

Three branches greater than 30 cm in length were collected from each of 10 colonies of staghorn *Acropora*. Transplants were collected from Middle Cay Reef on 12 February 1986, and transported in bins of water (travel time approximately 30 minutes). One branch from each of the colonies formed each treatment as follows:

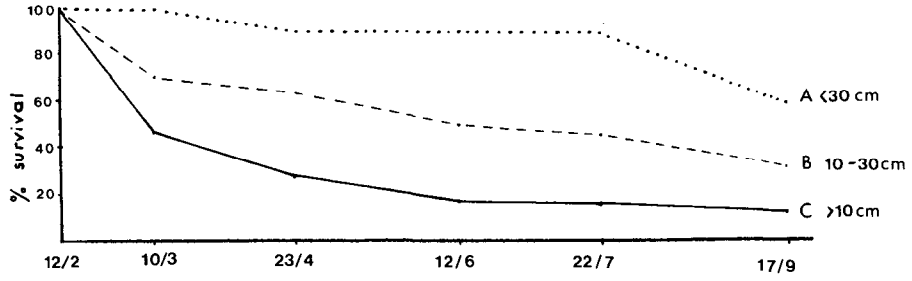
1. Fragments >30 cm long (10 fragments)
2. Fragments 10-30 cm long (28 pieces)
3. Fragments <10 cm long (47 pieces)

Transplants were deposited in the shallow backreef area at Green Island and censused at intervals of 1 to 2 months until September 1986.

RESULTS

Figure 10 shows survival rates for the 3 treatments over 7 months. Results are similar to those shown in figure 8, i.e. decreasing survival rates with decreasing fragment size. After about 2 months following transplantation, survival rate declines only slowly, indicating that most of the mortality due to the transplantation process has already occurred.

Figure 10. Effect of fragment size on the survival rate of branching *Acropora* (experiment 4).



CONCLUSION:

This experiment confirms the results of experiment 2, that small fragments have high mortality rates. It also indicates a falling off in the mortality rate about 2 months after transplantation.

EXPERIMENT 5

AIMS

To examine the effect of exposure to air during transportation on subsequent survival rate for a number of different taxa.

DESIGN

We collected 24 colonies or colony fragments of each of 3 taxonomic groups from Middle Cay Reef on 12 February 1986. They were then transported back to Green Island (travel time 40 minutes) either in bins of water or on the boat deck shaded from direct sunlight by a tarpaulin (12 colonies for each taxa for each treatment). Thus, the treatments were:

1. Branches of staghorn *Acropora* in water bins
2. Branches of staghorn *Acropora* on boat deck
3. *Pocillopora damicornis* in water bins
4. *Pocillopora damicornis* on boat deck
5. Massive faviid corals, in water bins
6. Massive faviid corals, on boat deck

For the *Acropora* and *P. damicornis* transplants, two fragments were generally collected from the same colony where possible so the two treatments contained virtually identical samples. For the faviids, pairs of colonies of the same species and approximately equal size were collected for the 2 samples. Corals were transplanted to the shallow backreef site, and monitored at 1 to 2 month intervals over the next 7 months.

RESULTS

There were no significant differences in the survival of the corals over the next 6 months, for any of the taxa. After 7 months, the number of survivors of the 12 corals originally transplanted for the 'in water' and 'on deck' treatments respectively was 10 and 10 for staghorn *Acropora*, 6 and 11 for *P. damicornis*, and 11 and 11 for massive faviids.

CONCLUSION:

There was no significant difference in survival rate of transplanted corals that can be attributed to transportation either in air or in water bins, when exposure to air was for a period of about 40 minutes. Survival rates of three different coral taxa were also very similar, for a period of 7 months, falling mostly in the range between 83% and 92%.

EXPERIMENT 6

AIMS

a. To compare survival rate of transplants at forereef and backreef site, and of branched versus unbranched *Acropora* fragments (to repeat experiment 3).

b. To check whether survival rate could be increased by either careful placement of the transplanted corals on the substratum, or by attachment of the transplanted corals to the existing reef structure.

DESIGN

We collected 6 branched fragments and 2 unbranched fragments from each of 14 large colonies of staghorn *Acropora* at Middle Cay Reef on 14 February 1986. There were 8 different treatments, each with a sample size of 14 fragments:

1. Branched fragment, forereef site, attached with string
2. Branched fragment, forereef site, carefully placed
3. Branched fragment, forereef site, randomly scattered
4. Unbranched fragment, forereef site, randomly scattered
5. Branched fragment, backreef site, attached with string
6. Branched fragment, backreef site, randomly scattered
7. Unbranched fragment, backreef site, randomly scattered

Corals were transplanted in bins of water to simulate the conditions of experiment 3, and transport time was approximately 30 to 40 minutes. Transplants were monitored at intervals of 1 to 2 months for 7 months.

RESULTS

a. Results of the first part of the experiment are given in table 5.

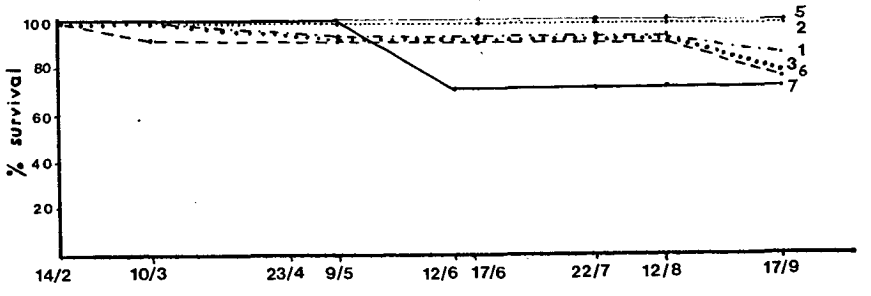
Table 5. Comparison of survival of branched and unbranched *Acropora* fragments in forereef and backreef sites. Initial sample size was 14.

	Unbranched	Branched
Forereef site	2	11
Backreef site	7	10

As was found in experiment 3, there was consistently higher survival of branched over unbranched fragments. There was , however, no clear relationship between location and survival. Unbranched fragments showed higher survival in the backreef site (as was found in experiment 3), while survival of branched fragments was not significantly different at the two sites.

b. Attachment methods. Results are presented in figure 11. There were no significant differences in survival rate that could be attributed to placement or attachment method. There were also no significant differences in survival between forereef and backreef sites for the treatments, with survival for some treatments slightly higher in the forereef and others in the backreef. Survival rates for all treatments ranged between 71% and 100% after 7 months.

Figure 11. Results of experiment 6b, testing the survival rate of transplants of *Acropora* using different methods of placement and attachment at forereef and backreef sites. The numbers on the graph in the figure relate to the treatment number given in the text.



CONCLUSION:

There was good survival for all treatments (apart from unbranched corals) in both forereef and backreef sites. Under the conditions during the study period, attachment and placement method had little effect on colony survival.

EXPERIMENT 7

AIMS

a. To test the effect of increasing periods of exposure to air during transportation on survival rates of transplanted fragments of branching *Acropora* which were carefully placed on the substrate, and if possible to determine the upper length of exposure time that would give reasonable survival.

b. To compare survival rate of corals attached by cable ties with those carefully placed and randomly scattered at a backreef site.

DESIGN

Five fragments with branching morphology were collected from each of 15 large colonies of staghorn *Acropora* at Middle Cay Reef on 15 May 1986. The five treatments (with sample size of 15 fragments) were as follows:

1. Attached with cable ties, exposed 45 minutes
2. Randomly scattered, exposed 45 minutes
3. Carefully placed, exposed 45 minutes
4. Carefully placed, exposed 90 minutes
5. Carefully placed, exposed 120 minutes

All corals were transported exposed to air but protected from direct sunlight. They were placed at the backreef transplant site in slightly deeper water than some of the other experiments (4 m at low tide rather than 3 m). For the corals attached with cable ties, the ties were placed around the base of the branch of the coral and attached to a pre-existing feature of the reef, usually a dead coral. Survival was monitored for 4 months following transplantation.

RESULTS

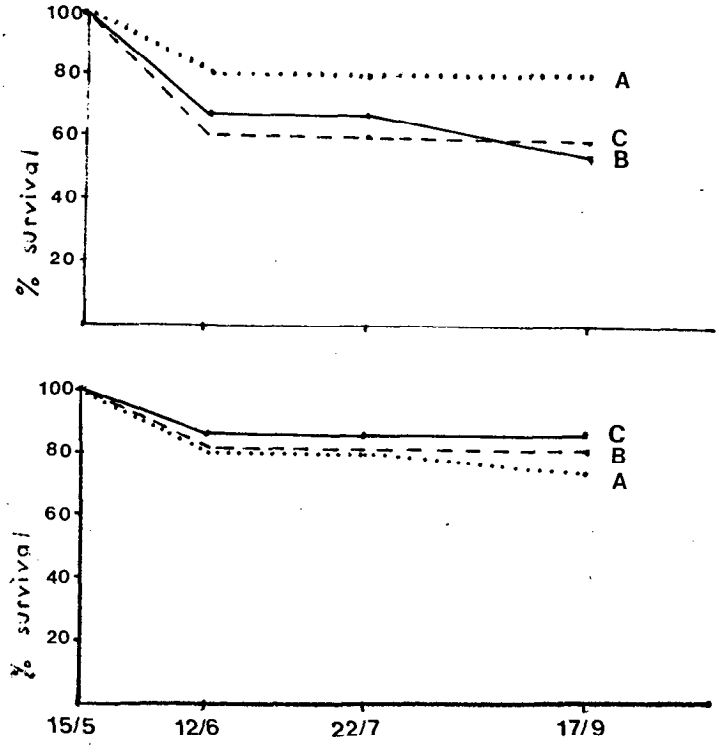
a. Results for variable exposure periods are shown in figure 12a. After 1 month there was a progressive decrease in survival with increasing exposure time, but survival ranged only between 69% and 80%. Survival rate levelled off after 1 month, but some colonies exposed for 90 minutes died between the 2nd and 4th month, so survival was actually slightly lower for the shorter exposure time after 4 months. It does not appear that the limiting time for exposure to air was reached in this experiment, i.e. a significant number of corals (>50%) survived exposure periods of 2 hours.

b. Results presented in figure 12b show that there was no significant effect of attachment method on survival rate for corals treated by the three different methods (carefully placed, randomly placed, tied with cable ties) during the study period. Survival rate levelled after the first month period.

Figure 12. Results of experiment 7, testing

(a) the effect of extending the period of exposure to air during transportation of *Acropora*. A=exposed 45 minutes; B=exposed 90 minutes; C=exposed 120 minutes. All corals were carefully placed.

(b) survival rates of *Acropora* fragments using different placement methods. A=attached using cable ties; B=randomly scattered; C=carefully placed. All corals were exposed to the air for 45 minutes.



CONCLUSIONS

There was a slight decline in survivorship for corals exposed to air for more than 45 minutes, but greater than 50% of corals survived longer than 4 months with exposures up to 2 hours.

Attachment method had little effect on subsequent survival of transplants under the conditions at the study site, confirming the results of experiment 6.

EXPERIMENT 8

AIMS

To determine the maximum period of exposure to air during transportation that would result in an acceptable level of coral mortality for transplants of two different coral taxa.

DESIGN

We collected 45 pieces of *Pocillopora damicornis* and 45 branches of staghorn *Acropora* from Middle Cay Reef on 26 July 1986. The corals were transplanted to a shallow backreef site at Green Island and were exposed to air (but shaded) for different periods. All colonies were placed in their normal growth orientations. Treatments were:

1. *Acropora* exposed 1 hour
2. *Acropora* exposed 2 hours
3. *Acropora* exposed 3 hours
4. *Pocillopora damicornis* exposed 1 hour
5. *Pocillopora damicornis* exposed 2 hours
6. *Pocillopora damicornis* exposed 3 hours

RESULTS

Surviviorship for the 2 taxa over the next 2 months are given in figure 13. In general, colonies of *P. damicornis* survived better than the *Acropora* fragments, although many of the *Pocillopora* colonies had dead tissue over a substantial part of the colony (partial mortality). For both taxa, survival rates declined with increasing periods of exposure. For *Acropora* fragments, survival after 2 months was less than 50% for both 2-hour and 3-hour exposures. Survival of *P. damicornis* after 2 hours exposure to air was over 90%, but survival rate dropped to <55% for an exposure time of 3 hours.

CONCLUSIONS

If transplanted corals are likely to be exposed to air for periods of more than 2 hours during transplantation, consideration should be given to transplanting pocilloporid rather than staghorn *Acropora* corals. Otherwise, it is advisable that periods of exposure be kept to less than 2 hours.

Figure 13. Results of experiment 8 where the effect on mortality of the period of exposure to air of two coral taxa was tested.

a. *Acropora* sp.
b. *Pocillopora damicornis*