ANALYSIS OF VISUALLY DOMINANT ORGANISM DATA FROM MANTA TOW CORAL SURVEYS

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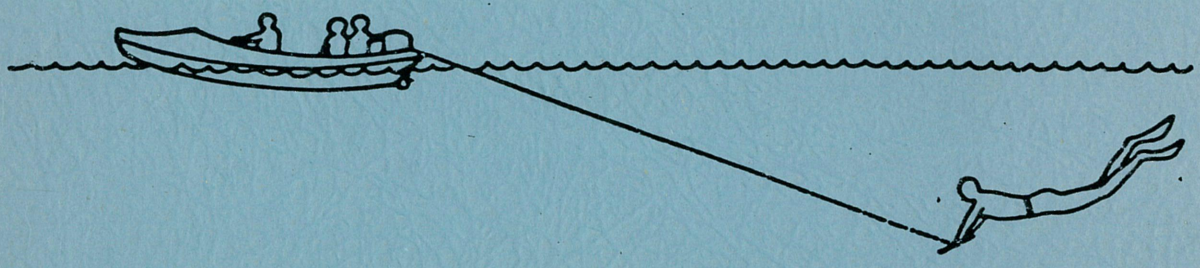

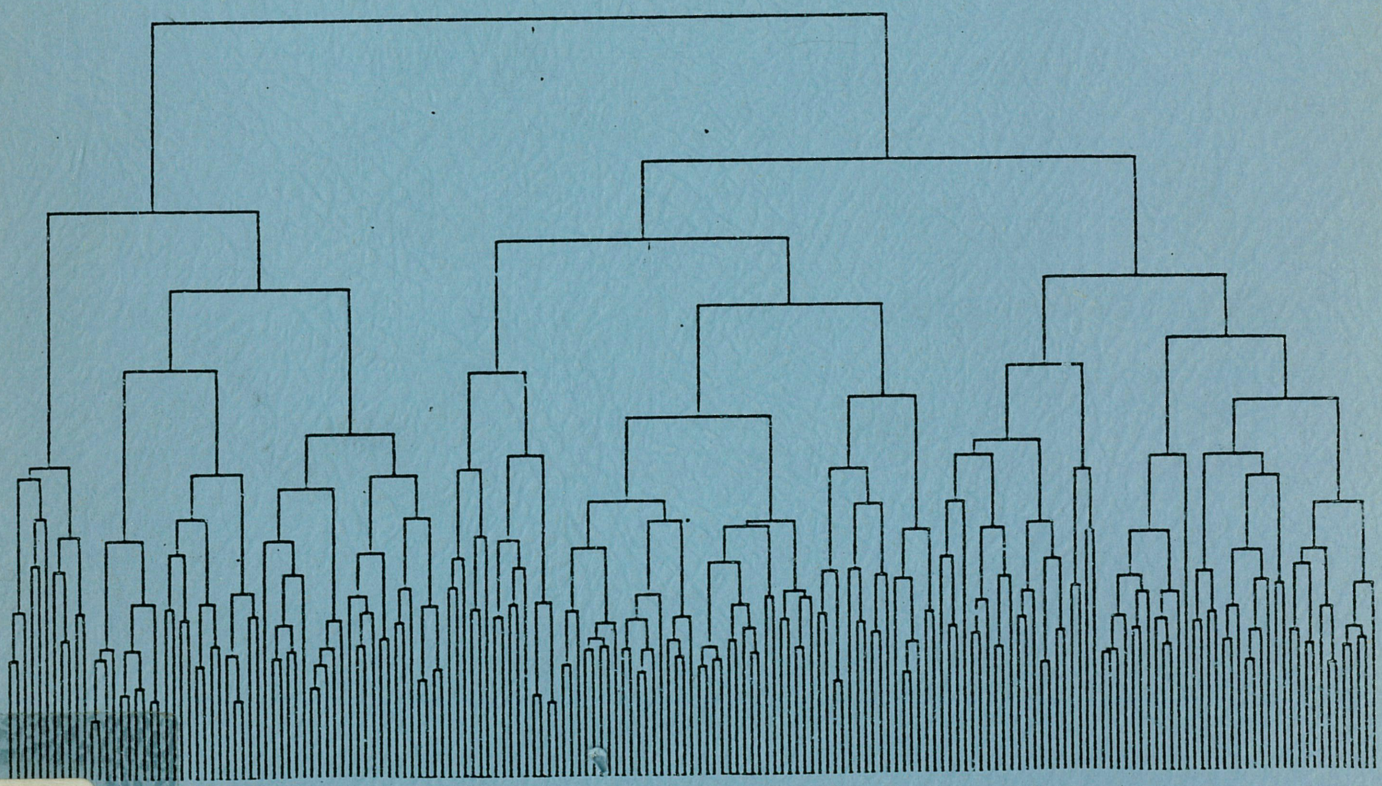

REPORT TO THE GREAT BARRIER REEF MARINE PARK AUTHORITY

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FOREWARD

This document is the final report from a consultancy undertaken in the Zoology Department, James Cook University for the Great Barrier Reef Marine Park Authority. Sections 1,2 and 3 represent the scientific report on the work undertaken, and section 4 (written in association with GBRMPA Staff, Len Zell and Sally Driml) is a discussion of findings which have implications for management of the Great Barrier Reef.

Numerical listings of the results of analyses, and the final community maps, will be presented to the Authority for archival separately from this written report.

The author gratefully acknowledges the help of the consultancy supervisor, Rhondda Jones of the Zoology Department James Cook University, and support of the Head of the School of Biological Sciences, Professor Burdon-Jones. Invaluable assistance with the multivariate analysis, using the TAXON library of programs, was provided by Dave Abel and Dennis Ross of the CSIRO Division of Computing Research. Paul Daniel produced the final maps. Thanks are also due to the staff of GBRMPA for their co-operation and support, in particular Len Zell, Richard Kenchington and Trevor Shearn but especially to Sally Driml.

1. INTRODUCTION

1.1 Background to the Manta Tow Method

The Manta Tow technique, as it was used for the surveys discussed in this report, was developed as a rapid visual reconnaissance method for the GBRMPA. It is intended to provide a broad scale physical and biological characterisation of large numbers of reefs as an aid to reef management planning.

The method involves an observer being towed around a reef behind a small boat for distances of up to 1km. The observer mentally divides the section of reef that he has seen into a series of zones (numbering from one to up to six). For each zone the observer records scores for a series of physiographic and biological attributes. The data recording is in three parts:

1, the physical attributes (substrate, slope, depth etc.)

2, the amount of substrate covered by living benthic organisms (hard corals, soft corals and macroalgae) and

3, the relative cover of benthic organisms in a series of Visually Dominant Organism (V.D.O.) categories.

The VDO categories and their code numbers are presented in Appendix I (pages 1 and 2). "VDO" is an umbrella term which encompasses three levels of taxonomic/morphologic resolution. The highest level of resolution (the "93 group level" Done *et al*, 1981) contains a mixture of genera, species and ecomorphs. Categories at the 93 group level are grouped successively into 34 minor and then 8 major categories (the "34 group level" and the "8 group level", Done *et al*, 1981). Observers are required to record to the highest resolution level that they can recognise.

The physical and cover attributes are recorded in such a way that they can be represented on a series of shaded diagrammatic maps of the surveyed reefs. Details of the methods used for production of such maps are given in Done (1980 Appendix I). The shaded maps provided an easily interpretable summary of large volumes of data. The VDO scores, however, do not lend themselves to simple mapping, and some form of synthetic interpretive analysis is required before the data are particularly useful.

1.2 Previous Work on Analysis of VDO Data

To date the only work on analysis of VDO data from Manta Tows is that of Done (1980). He analysed data from surveys of the Capricorn Bunker area done in 1978. He used each zone of each tow as an individual site and grouped the sites on the basis of hard coral VDO scores using an agglomerative hierarchical cluster analysis technique.

Diagnostic constant VDOs (ones which occurred in at least two thirds of sites in a group) were used to characterise the site groups. The distributions of the site groups and their constant VDOs, determined separately for each of four observers, enabled definition of a series of "ubiquitous coral assemblages". The positions of the assemblages were then plotted on outlines of the reefs surveyed.

In his discussion, Done (1980) highlighted "unquantifiable intra and inter observer inconsistencies" due to differences in background and training, as one of the major deficiencies of the surveys done up till then. This meant that a number of simplifying manipulations were required before the data could be analysed. Reduction of scores from the full seven point scale to a four point scale was used to smooth out differences between observers' cover scores. Inconsistencies between observers' appreciation of VDO categories meant that each

observer's data had to be analysed separately. Only hard coral VDOs were used in the analysis. Most VDOs had to be reduced from the highest resolution level ("93 group", Done *et al* 1981) to a lower level (mostly the "34 group" level).

1.3 The data studied

The data analysed for this report were from surveys of five cross-shelf transects of reefs at Innisfail, Cairns, Port Douglas, Cooktown and Lizard Island. Details of the surveys and the positions of the reefs are tabled in a GBRMPA report (Zell, 1980), incorporated herein as Appendix I. The surveys were done over a three month period in early 1980, using a core of four specially trained observers. By using only a small number of well-trained observers it was hoped to bypass some of the problems of observer inconsistency.

A total of 536 tows on 49 reefs was completed. These provided a grand total of 1196 sites with VDO definitions to be analysed. The physical and cover attribute scores from these surveys have already been mapped as part of a separate contract. Bound copies of the maps have been produced (GBRMPA, unpublished).

In addition to the actual surveys, a series of test tows was done on Arlington Reef, near Cairns where the four trained observers were towed simultaneously over the same paths and debriefed independently.

1.4 Work undertaken for the consultancy

Work undertaken was in three broad sections. The first was to assess the deficiencies and limitations of the data, to determine a valid sensitivity level at which the data could be used. The second

was to determine and test the most appropriate analysis technique for the data. This required assessment of analyses on both their validity and the usefulness of the results they produced. Testing was done on a subset of the survey data and the results were presented to a group of GBRMPA staff and coral specialists for assessment. In the third section a variant of the tested method was used on the whole data set.

All stages of the analysis provided input for formulation of a number of recommendations and suggestions for improvement of the field method.

2. TESTING THE DATA AND ANALYSIS METHODS

2.1 Introduction

Up to eight hard coral and up to eight soft coral VDOs are scored for each site defined (see sample data sheet and VDO table in Appendix I). Cover for each chosen VDO category is recorded (raw scores) as a percentage of the previously scored overall Hard Coral or Soft Coral Cover to that site. Overall cover and relative cover of VDOs are scored on the same 0-6 scale (see Appendix I, page 1). Previous VDO analysis used only the raw scores of Hard Coral categories. For this study it was hoped to develop and validate a method of data manipulation which would allow inclusion of all validly scored VDO categories (Hard and Soft corals, and "Others") in a single analysis. Raw scores of different categories cannot be mixed because the resulting matrix is likely to be overly weighted by inappropriate categories. At one site, for example, there might be 75-100% Hard Coral Cover but only 1-5% Soft Coral Cover. Five hard coral VDOs might be recorded (raw scores 4,3,2,1,1) but only one soft coral category (raw score 6).

By scaling the raw scores according to the appropriate overall cover grading, a "Ground Cover" value can be derived. There is a problem of definition of relative cover for the "Others" categories (sponges, hydroids and ascidians); they are simply scored as present (either grade 1 or 6 depending on the observer). In addition they do not fall into any of the overall cover categories, and so when recorded they were artificially assigned an arbitrary, fairly low cover score.

The manta tow method allows for three levels of definition of VDOs. In this data set most are recorded to the 93 group level, but many records at lower resolution are present. In order to avoid

having a mixture of levels in any category, all scores had to be reduced to the 34 group level.

Previous analyses of VDO data were hindered by inter and intra observer differences. These differences show up as inconsistencies in choice of VDO categories to be used, and in the actual scores that are given. For this study it was hoped to determine a sensitivity level for data useage at which observer variability could safely be ignored. True ground truthing for visual surveys of the large areas covered by manta towing is not likely to be a simple proposition; what is required in this context is good within and between observer consistency. Only four observers were used for collection of the data analysed here. They were specially trained for these surveys and it was hoped that inconsistencies would be minimised.

The Test Tows on Arlington Reef provide extremely useful data with which to investigate problems of observer variability, a subject only indirectly addressed in the past. In particular the repeated tows were used to determine whether the four observers ranked a set of VDOs in a similar manner or not.

Some form of pattern analysis to extract useful generalisations and summary information about the large number of sites and attributes in this data set seemed appropriate. Done (1980) used hierarchical cluster analysis to define groups of sites and hard coral assemblages occurring there. Similar methods were tested on the Arlington Reef Test Tow data. The Lizard Island Transect of sites were then used to derive the sort of community patterns which might be expected from the data as a whole. This transect was chosen because of the author's personal familiarity with the area.

2.2 Methods

2.2.1 Data manipulations

For the conversion of all scores to the 34 group level, graded scores were replaced with the mid-point of the appropriate percentage range. This was necessary because of the non-linearity of the 0-6 scoring scale; two grade 4 scores (30-50%) for instance, cannot simply be summed to form a score of 8. VDOs scored at the 93 group level could then be fused to their respective 34 group category.

The Hard Coral Cover and Soft Coral Cover values for each site were similarly converted to the appropriate percentage cover value and used to scale their respective VDOs in the following manner:-

$$\text{VDO Ground Cover, \%} = \frac{A \times B}{100}$$

A = VDO raw Score (converted to %)

B = Hard Coral or Soft Coral Cover (converted to %)

Non-coral VDOs (sponges, Hydroids and Ascidians) were assigned an arbitrary ground cover of 10%.

2.2.2 Testing of observer consistency

For all of the repeated test tows (6 tows over the same path by 4 observers) all observers defined a "back reef patches" site with hard coral cover estimates of 1 to 4 and soft coral cover of 3 to 5. These provided 15 within observer and 54 between observer pairs of replicated tows for each observer. A total of 16 of the 34 group level, coral VDO categories were recorded. Spearman Rank Order correlation coefficients were calculated for every pair of observer/tow combinations using the VDO ground cover percentages.

2.2.3 Cluster analysis of Test Tows

All the Test Tow sites (103) were clustered using the ground cover scores of their VDOs. The analyses were done using the CLUSTAN package on the JCU computer system (Wishart, 1978). A variety of dissimilarity indices were used (see section 2.3)

2.2.4 Cluster analysis of the Lizard Island Transect sites

The 335 sites in the Lizard Island transect were grouped using the Bray Curtis dissimilarity index (on Log(N+1) transformed ground cover scores) and Lance Williams Flexible β sorting. Eight major site groups were distinguished and their respective associations of VDOs defined. VDO categories that were used as "diagnostics" for definition of associations were those with scores which were less variable within the site group than in the data as a whole (CLUSTAN "RESULTS" F-ratio $<$ 1) and which had higher mean scores within the group than in the data as a whole (CLUSTAN "RESULTS" T-value $<<0$).

2.3 Results

2.3.1 Observer Consistency

In nearly all cases, replicate tow correlations were satisfactory (differences not significant, $P>0.05$). The only exception was one of the last tows done on the last day of three months of field work when the observers relaxed their concentration. Many of the replicates had correlations equal to or close to 1.0.

2.3.2 Cluster analysis of Test Tows

The most satisfactory results were obtained using the Bray-Curtis dissimilarity index and Lance-Williams flexible β sorting on Log (N+1) transformed data. Other indices including squared Euclidean Distance and Bray Curtis on non-transformed data gave results that were too heavily weighted by the very abundant categories.

All 24 repeated tow sites clustered closely together along with other sites from similar back reef areas. Other replicated sites appeared in the same site groups whenever it was clear that the same zone divisions had been defined by the different observers.

2.3.3 Cluster Analysis of the Lizard Island Transect sites.

The eight associations defined for the Lizard Island sites are presented in table 1. They are ordered in an approximate ranking from "most exposed" to "least exposed" according to their distributions on reefs in the transect. It must be remembered that only the diagnostic VDOs are tabulated. Others may be abundant at particular sites but not consistent within the group as a whole.

TABLE 1: **The eight assemblages, their diagnostic VDOs and descriptions of their distributions, as defined for the Lizard Island transect of sites.**

Numbers of sites in each group	*Acropora humilis*	*Acropora palifera / cuneata*	Ceroid/Plocoid Corallites	Staghorn *Acropora*	Massive *Porites*	Tabulate *Acropora*	Erect Fleshy Soft Corals	Prostrate Fleshy Soft Corals	Distribution of the associations on the cross-shelf transect of reefs
35	X	X							Crests and upper slopes of outer reefs and exposed tops on Lizard Is.
48	X	X					X	X	Tops and crests of outer reefs and exposed side of Lizard Is.
24	X		X				X	X	Bommie and back-reef tops on outer reefs and back-reef tops and patches on Lizard Is.
16			X						Semi-exposed tops
65				X	X	X	X	X	Exposed slope sites throughout
58					X		X	X	Lower slopes and lagoon and bottom patches
58			X	X			X		Lower slopes and lagoon and back-reef patches
30				X	X				Lower slopes and deep bottoms

The distributions of assemblages were mapped on diagrammatic reef outlines. The outlines used were the same as those on the black and white shaded maps of the physical and cover attributes.

2.4 Discussion

Reduction of all VDOs to the 34 group level results in an obvious loss of information in some cases. However the VDOs are deliberately tabulated in a hierarchical manner. This allows observers to score each VDO at a resolution level which they can confidently recognise. Their confidence will clearly vary with training and experience, but will also vary with changes in factors such as water clarity, fatigue, temperature and weather. So scores at a low resolution level are likely to occur no matter how experienced the observer. Use of a consistent level is vital for sensible analysis, and the 34 group level for all categories was considered the most appropriate for these data.

The use of ground cover values has important advantages over the raw VDO relative scores used in previous work. It allows inclusion of all categories of VDO in the same analyses. It also assists in differentiation between sites with the same or similar VDO composition, but with different overall cover.

The results of the tests of observer consistency indicate that observer differences are insignificant if the data are treated in the manner used. The fact that observer inconsistencies can be ignored, without the need for any further manipulations to simplify the data, is another major improvement on the work from previous surveys.

Interestingly, within observer correlations were not significantly better than between observer correlations. This implies that the use of any individual's data to a more detailed level is not likely to be fruitful. The high level of inter observer consistency appears to vindicate the use of a small, consistent group of specially trained observers.

The cluster analysis of the Test Tows provided further indications that observer differences can be ignored when the data are used in this manner, and also allowed testing of clustering strategies. The dissimilarity index finally chosen gives similar results to that tested and chosen by Done (1980). The index he used, Canberra Metric, is not available in the CLUSTAN package.

The eight assemblages defined appear to provide a sensible characterisation of the benthic communities in the Lizard Island area. They can be readily placed in an approximate ranking from most to least exposed according to their vertical positions and cross-shelf distributions. Of the 34 VDO categories, only 8 appear to be important for defining the community groups. The most significant break is between those sites with high scores for *Acropora humilis* and those without. This species appears to be particularly useful for differentiating exposed sites (shallow and off-shore).

The use of colour for map presentation of the assemblage distributions enabled the production of shaded maps which are directly analogous to the shaded maps of physical and cover attributes. It was felt that the number of categories could not be adequately represented by monochrome shadings or hatchings. These maps had to be produced by

hand, as no appropriate computer based colour mapping is locally available. Use of colour rather than black and white will add to the cost of production of survey maps which will cost more to reproduce.

Defining a number of assemblages of organisms is a useful way of synthesising a summary of the large volume of data. The validity of the results of such techniques is best judged on their biological sense; their usefulness can only be judged by reef management policy makers. The consultancy workshop (held on 19.8.83) was a useful way to have these issues assessed on the results of the Lizard Island analysis. It was generally felt, by the participants, that any lack of definition in the patterns, was caused by limitations of the survey technique. It was suggested that similar analyses of the whole data set were worth pursuing. The workshop discussions are summarised by Driml (1983), and further discussed in section 4.

3. ANALYSIS OF THE WHOLE DATA SET

3.1 Introduction

Having established a satisfactory set of manipulations for the data which enable the use of all VDO categories and a level at which observer variability could be ignored, it was decided by the consultant and GBRMPA staff to proceed with the sort of analysis which had proved successful for the Lizard Island Transect. It had already become apparent that the size of matrices involved (334 sites in the Lizard Island set) could not be handled efficiently by the CLUSTAN package at JCU. It was decided to use the CSIRO Division of Computing Research, TAXON library of programs. TAXON provides a very comprehensive set of analysis and diagnostic programs for numerical taxonomy, which can handle large data sets efficiently.

The 1196 sites in the whole data set are divided into 5 unequal sized transects. The cost of running most agglomerative hierarchical procedures increases approximately with the square of the number of sites to be analysed. Because of the expense, it had been anticipated that the five transects would have to be analysed separately. Use of TAXON however offered the possibility of analysing all 1200 sites at once, a more attractive proposition as it allows much easier north/south as well as across transect comparisons of community distributions. Even using TAXON, the size of the data set required the choice of a relatively computationally cheap procedure.

The Numerical Information Analysis, Partitionable procedure (Williams, 1972;1973) was used. The method is slightly different in approach from the methods tested on the Arlington Reef and Lizard Island transect data. An information statistic is calculated, rather than a metric distance, and sites are fused into groups on the basis of minimum information gain for each fusion.

3.2 Methods

In order to keep the matrix as small as possible, a check was made for pairs or groups of sites with identical scores for all attributes. If left in the matrix, such sites would be fused immediately because of their zero information difference; their removal reduced the matrix to 1151 sites (by 34 attributes).

A classification of the sites was made using the TAXON, NIAP Program, with the option invoked to use attributes both qualitatively and quantitatively. This job required 96% of the total available memory of the CSIRO, CYBER7600 computer! The TABOUT progam was used to list group membership and attribute statistics for groups.

3.3 Results

Ten final site groups were extracted from the classification for mapping and detailed discussion. Ten was chosen as a manageable number of VDO associations to define and map, although significant differences are discernable between site groups at the 15 to 20 group levels. As can be seen from the dendrogram (figure 1) three major groups are present:

A- which includes groups 1,2 and 3 is made up of sites dominated by *Acropora humilis*.

B- including groups 4 and 10, sites with low cover and diversity.

C- groups 5,6,7,8 and 9, a loose group incorporating all the remaining sites.

FIGURE 1: Dendrogram showing fusion of the final 20 groups from classification of all 1196 sites. The ten site groups discussed are numbered (the number of sites in each group is in parentheses).

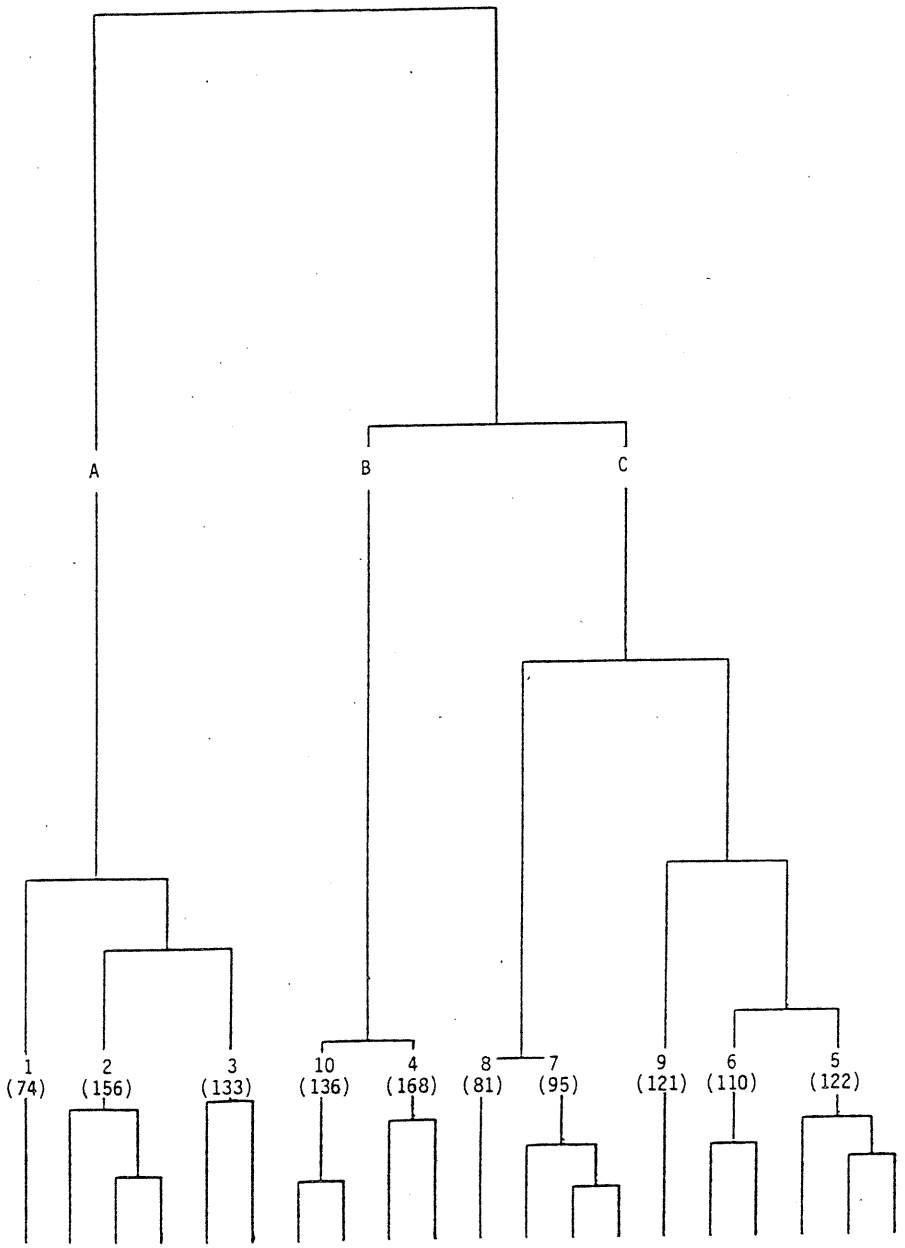

TABLE 2: Ten assemblages and their diagnostic VDOs as defined by analysis of all 1196 sites.

Assemblage number	Number of sites	*Acropora humilis*	*Acropora palifera*	Ceroid/Plocoid Corallites	Staghorn *Acropora*	Massive *Porites*	Tabulate *Acropora*	*Pocillopora damicornis*	Branching finger-thick	Laminar, explante with free lip	Erect fleshy Soft Corals	Prostrate fleshy Soft Corals	Fan and whip Gorgonians
1	74	X	X										
2	156	X									X	X	
3	133	X					X				X	X	
4	168			X									
5	122							X			X		
6	110				X		X				X		
7	95					X			X		X	X	
8	81			X	X	X		X			X	X	X
9	121				X					X	X		
10	136				X	X							

The VDO associations for each of the site groups are defined on the basis of their diagnostic VDOs (Table 2). Categories used as diagnostic of assemblages are ones which occur in at least three-quarters of the sites in a group and which have a mean ground cover of at least 15%.

The diagnostic constant VDOs for each assemblage are listed below with a brief description of the distributions of assemblages at sites in the five transects.

1. *Acropora humilis* and *A. palifera/cuneata*

   - restricted in distribution to the reef tops and crests of outer continental shelf reefs, in particular the ribbon reefs of the Lizard Island and Cooktown transects.

2. *Acropora humilis* and Erect and Prostrate Soft Corals

   - occurs on slightly less exposed tops, crests and shallow backreef areas on mid and outer shelf reefs.

3. *Acropora humilis* and Tabulate *Acropora*

   - found on the slopes of mid shelf reefs, especially in the Cairns, Port Douglas and Cooktown transects.

4. Ceroid/Plocoid Corallites (mostly small polyped Faviids)

   - one of the low cover, low diversity assemblages
   - restricted to mid and inshore shallow lagoon sites.

5. *Pocillopora damicornis* and Erect Soft Corals

   - mainly lagoon and sheltered slope sites.

6. Staghorn *Acropora*, Tabulate *Acropora* and Erect Soft Corals
   - found on shallow sheltered slope sites, especially in the southern transects

7. Massive Porites, Branching-finger-thick, Erect and Prostrate Soft Corals
   - occurs mainly on middle and offshore back reef slopes.

8. Ceroid/Plocoid, Staghorn *Acropora*, *Porites*, *Pocillopora damicornis* Erect and Prostrate Soft Corals, and Gorgonians
   - Found on sheltered mid shelf slope and lagoon sites.

9. Staghorn *Acropora* and Laminar with free lip
   - restricted to sheltered low slopes.

10. Staghorn *Acropora* and Massive *Porites*
    - low cover and low diversity assemblage occurring on deep slopes and reef bottoms.

The distributions of the assemblages have been mapped (to be presented separately from this report). Insufficient time and expertise were available for colour maps. The assemblage numbers relating to each zone of each tow are superimposed on the shaded maps of hard coral cover.

3.4 Discussion

The dominant organisms recorded at particular sites and the resulting assemblages appear to be most easily explained by the exposure of sites; exposure being a complex combination of depth and

wave action gradients. The assemblages are numbered in an approximate ranking from most to least exposed. The cross transect distributions of assemblages appear to reflect cross shelf gradients of exposure. North-south differences between transects seem to be a result of differences in the morphology of different parts of the continental shelf and the distribution of reefs on the shelf. The effect of the ribbon reefs in the northern transects on the exposure of the mid shelf reefs is particularly noticable.

The assemblages defined provide a characterisation of the communities on the reefs surveyed. The assemblage distribution maps should provide an important biological supplement to the existing substrate and cover maps.

4. SUGGESTIONS FOR MODIFICATIONS TO THE MANTA TOW METHOD

Use of the Manta Tow method for reconnaissance and monitoring is likely to increase in the future. Before any further surveys are undertaken using the method it should be improved to enhance ease of data use and its value for management staff.

All stages of the analysis, and discussions during the consultancy workshop, have provided input for a series of suggestions for the conduct of future surveys and modifications to the method.

(1) The good levels of observer consistency in the northern survey data, suggest that the use of a small, constant group of observers is very advantageous.

(2) Whatever combinations of observers are used, replicated tows should be done regularly e.g. weekly to enable testing of inter and intra observer consistency. These should take the same form as the Arlington Reef Test Tows i.e. all observers towed over exactly the same path simultaneously, with at least four tows over the same path, separated by tows in different areas and at least four hours.

(3) Because of the sinuous nature of the tow path observers are towed across zone changes continually, and may continue to tow for a full 20 minutes without recognising major reef edge differences. This can lead to lack of definition of major changes in communities, especially on small reefs. It is possible to delineate major division points around reefs in advance, from aerial photographs or landsat images. This would ensure that observers are not towed through several

physically different reef areas which could be expected to offer a range of communities.

(4) Lack of defined numbers for most zone divisions used on the data sheets, means that continual reference has to be made to verbal zone descriptions during interpretation; only two categories (1-reef top and 2-reef crest) were initially defined. A new "crib sheet" has been developed (Appendix I, page 6) which has 15 physically different reef categories visually defined. This should be used in all future surveys.

(5) There is scope for improvement in the definition and scoring of VDOs. It should be possible for instance to drastically reduce the number of VDOs scored, and yet still be able to extract generalised community types in the same manner as has been done for the five northern transects. A short list of "important" categories could be defined for specific scoring rather than the present scoring by choice. The list could be derived from the VDO sheet, community groups defined in this report and the results of other community typing work such as Done (1983).

It is clear that there have been inconsistencies in the useage of at least some of the present VDO list. Distributions of VDO useage by observer can be used to highlight poorly used categories e.g. Table 3.

If all observers towed all kinds of communities equally and their appreciation of each VDO is the same, the distributions of useage should be similar. There are obvious problems with some categories e.g. VDO 250 "meandroid

fleshy". Such poorly used VDOs pinpointed in this manner should be removed if considered "unimportant" or special stress could be placed on their definition during observer training.

(6) If they are to be kept in the VDO list, some protocol for recording "others" categories (sponges, hydroids and ascidians) needs to be defined e.g. scoring directly as a ground cover score.

(7) The reliability of information from manta towing varies with water clarity, temperature and sea state, factors not presently recorded. Scoring of a reliability index should be instigated using the same six point scale as is defined for aesthetics (Appendix I, page 6).

TABLE 3: Percentage frequency of VDO usage by observer for the 335 Lizard Island transect sites.

		OBSERVERS				
34 GROUP	LEVEL V.D.O. CATEGORY	ALL	13	14	15	16
810	ERECT FLESHY SOFT	66	61	55	70	76
210	*Porites*	61	59	55	65	67
340	*Acropora* STAG	53	54	48	51	58
820	PROSTRATE FLESHY SOFT	52	33	51	64	63
320	*Acropora humilis*	50	30	30	54	77
230	CEROID/PLOCOID	46	40	40	43	59
310	*Acropora* TABULATE	36	29	44	45	27
420	BRANCHING FINGERS	35	25	26	49	41
330	*Acropora palifera*	31	24	32	36	32
530	EXPLANATE FREE LIP	20	25	14	26	15
460	*Pocillopora damicornis*	18	21	16	16	20
350	*Acropora* BUSHY	16	24	19	14	8
450	BRANCHING STUBBY	16	14	14	18	16
250	MEANDROID FLESHY	13	10	9	36	1
830	FANS & WHIPS	13	17	10	9	14
410	*Seriatopora*	12	12	22	11	5
360	*Acropora* BOTTLE BRUSH	12	11	17	9	11
240	MEANDROID FINE	11	15	10	4	12
260	MASSIVE KNOBS & DENTS	6	2	3	20	*
510	ENCRUSTING NO LIP	6	4	8	12	*
570	VASES & ROSES	4	5	5	7	*
540	EXPLANATE VERTICAL PROJECTIONS	3	7	5	1	*
440	BRANCHING CLUBS	3	2	14	9	*
910	SPONGES	1	1	4	1	*
610	POLYPS EXTENDED	1	2	*	*	2
720	SOLITARY ELONGATE FUNGIIDS	1	*	4	1	*
220	MASSIVE SMALL CORALLITES	1	*	1	3	*
920	HYDROIDS	1	3	*	*	*
710	SOLITARY ROUND FUNDIIDS	1	1	1	*	*
520	ENCRUSTING VERTICAL PROJECTIONS	1	*	*	3	*
470	*Dendrophyllia nigrescens*	<1	1	*	*	*
560	LEAFY EXPLANATE	<1	1	*	*	*
930	ASCIDIANS	<1	*	1	*	*
730	SOLITARY OTHER FUNDIIDS	*	*	*	*	*

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APPENDIX I

Sample Data Sheets and VDO list as used

for the 1980 surveys, and updated versions.

1. Visually Dominant Organisms Reference table.

2. VDO list showing grouping of 93 group level categories to the 34 group and 8 group levels (from Done *et al*, 1981).

3. 1980 Data recording sheet.

4. 1980 "Crib sheet".

5. Present Data recording sheet, Note inclusion of Crown-of-thorns scoring.

6. Present "Crib sheet":. Note "Reef Community numbers"

GREAT BARRIER REEF MARINE PARK AUTHORITY

CORAL IDENTIKIT CODES

FOR MANTA TOW SURVEY

MASSIVE COLONIES

211 PORITES LARGE HEADS 30cm
212 PORITES SMALL HEADS 30cm

220 SMALL CORALLITES (Unspecified)

230 CERIOD PLOCOID (Unspecified)
231 DIPLOASTREA

240 FINE MEANDROID (Unspecified)
241 LEPTORIA
242 PLATYGYRA

250 FLESHY MEANDROID (Unspecified)
251 LOBOPHYLLIA
252 SYMPHYLLIA

260 MASSIVE WITH KNOBS or DENTS (Unspecified)
261 FAVIA STELLIGERA
262 PAVONA CLAVUS
263 HELIOPORA
264 SYNAREA
265 MILLEPORA
266 PSAMMOCORA
267 GALAXEA
268 GARDINOSERIS
269 PAVONA MINUTA

Code	%
0	0
1	1-5
2	5-15
3	15-30
4	30-50
5	50-75
6	75-100

ACROPORA

310 TABULATE (Unspecified)
311 A.HYACINTHUS TYPE

320 A.HUMILUS

A. PALIFERA

331 SHEETS
332 RIDGED
333 CLAVIFORM
334 COLUMNAR

STAGHORN

341 HIGH THICKETS (>2 FEET)
342 LOW THICKETS (<2 FEET)
343 HIGH CLUMPS (>2 FEET)
344 LOW CLUMPS (<2 FEET)
345 A.FLORIDA
346 A.'ROBUSTA' GROUP

350 BUSHLIKE ACROPORA (Unspecified)
351 BUSHY DENSE
352 BUSHY OPEN

360 BOTTLEBRUSH ACROPORA (Unspecified)
361 A.ECHINATA
362 XMAS TREE TYPE

BRANCHED CORALS

410 NEEDLE CORAL SERIATOPORA

420 FINGER THICK BRANCHING
421 MILLEPORA
422 ANACROPORA
423 HYDNOPHORA RIGIDA
424 CLAVARINA
425 ECHINOPORA
426 ACRHELIA
427 PORITES
428 MONTIPORA
429 PALAUASTREA
431 STYLOPHORA PISTILLATA
432 TUBASTREA
433 CAULASTREA

440 CLUB-LIKE BRANCHES (Unspecified)
441 POCILLOPORA EYDOUXI

450 STUBBY BRANCHES (Unspecified)
451 POCILLOPORA VERRUCOSA

460 POCILLOPORA DAMICORNIS

470 DENDROPHYLLIA NIGRANS

SHEET CORALS

510 ENCRUSTING-NO FREE LIP (Unspecified)
511 MILLEPORA
512 MONTIPORA
513 PORITES
514 FAVIDS (EERIOD PLOCOIDS)
515 TURBINARIA
516 ECHINOPORA

520 ENCRUSTING WITH VERTICAL PROJECTIONS (Unspecified)
521 HYDNOPHORA EXESA
522 MONTIPORA
523 GALAXEA

530 EXPLANATE - WITH FREE LIP (Unspecified)
531 MYCEDIUM/ECHINOPHYLLIA/OXPORA
532 MONTIPORA
533 TURBINARIA
534 PODABACIA/LITHOPHYLLON
535 PACHYSERIS
536 LEPTOSERIS
537 ECHINOPORA
538 MERULINA

540 EXPLANATE WITH VERTICAL PROJECTIONS (Unspecified)
541 SCAPOPHYLLIA
542 MERULINA
543 ECHINOPORA MAMMIFORMIS
544 PORITES LICHEN TYPE
546 MONTIPORA
547 PAVONA DECUSSATA
549 PECTINIA
551 PACHYSERIS RUGOSA

560 LEAFY EXPLANATE (Unspecified)
561 PAVONA CACTUS
562 LEPTOSERIS
563 PECTINIA

570 VASES/ROSES (Unspecified)
571 MONTIPORA
572 TURBINARIA
573 ECHINOPORA
574 PODABACIA
575 LEPTOSERIS

610 HARD CORALS WITH POLYPS EXTENDED
611 GONIOPORA/ALVEOPORA
612 EUPHYLLIA
613 PHYSOGYRA
614 TUBIPORA MUSICA
615 CATALAPHYLLIA

SOLITARY FREELIVING CORALS

710 ECONGATE FUNGIIDS (Unspecified)
711 HELIOFUNGIA ACTINIFORMIS
712 CYCLOSERIS
713 DIASERIS

720 ELONGATE FUNGIIDS (Unspecified)

730 SINGLE FLESHY POLYP
731 SCOLYMIA
732 TRACHYPHYLLIA
733 CYNARINA

740 BASKET CORALS (Unspecified)

SOFT CORALS

810 ERECT FLESHY CORALS
811 TUFTY LOW (Unspecified)
812 MASSIVE BRANCHING
813 SARCOPHYTON
814 SPIKEY SOFTS
815 XENIIDAE

820 PROSTRATE FLESHY CORALS
821 MASSIVE PROSTRATE
822 THIN ENCRUSTING
823 ZOOANTHIDS

SEA FANS AND WHIPS

831 FAN
832 WHIP
833 COMB
834 RUMPHELLA
835 BLACK CORAL BUSH

910 SPONGE
911 ENCRUSTING RIDGED SPONGE
912 VERTICAL LEAF SPONGE
913 VASE/CUP
914 ENCRUSTING (Unspecified)

STINGING HYDROIDS

921 BROWN FEATHER
922 WHITE FINE

ASCIDIANS

930 ASCIDIANS (Unspecified)
931 SMALL WHITE COLONIAL

8 GROUP LEVEL	34 GROUP LEVEL	93 GROUP LEVEL (NO. OF TYPES)
200 MASSIVE	210 *PORITES*	2
	220 SMALL CORALLITES	1
	230 CERIOD/PLOCOID CORALLITES	2
	240 MEANDROID CORALLITES – FINE	2
	250 MEANDROID CORALLITES – FLESHY	2
	260 MASSIVE WITH INDENTATIONS	6
300 *ACROPORA*	310 TABULATE	2
	320 *A. HUMILIS*	1
	330 *A. PALIFERA/CUNEATA*	4
	340 STAGHORN	6
	350 CAESPITOSE	2
	360 BUSHY/BOTTLEBRUSH	3
400 BRANCHING CORALS (NON *ACROPORA*)	410 *SERIATOPORA*	1
	420 FINGER THICK BRANCHING	13
	440 CLUB-LIKE BRANCHES	1
	450 SHORT THICK BRANCHES	2
	460 *POCILLOPORA DAMICORNIS*	1
	470 *DENDROPHYLLA NIGRANS*	1
500 LAMINAR	510 ENCRUSTING	6
	520 ENCRUSTING WITH VERTICAL PROJECTIONS	3
	530 EXPLANATE	8
	540 EXPLANATE WITH VERTICAL PROJECTIONS	11
	560 LEAFY EXPLANATE	4
	570 FOLIOSE ERECT	4
600 HARD CORALS WITH POLYPS EXTENDED	610 HARD CORALS WITH POLYPS EXTENDED	4
700 SOLITARY CORALS	710 ROUND FUNGIIDS	3
	720 ELONGATE FUNGIIDS	4
	730 OTHER ELONGATE	2
800 ALCYONARIA AND ANTIPATHARIA	810 ERECT FLESHY CORALS	5
	820 PROSTRATE FLESHY CORALS	3
	830 SEA FANS AND SEA WHIPS	5
900 OTHER	910 SPONGES	4
	920 STINGING HYDROIDS	2
	930 ASCIDIANS	2

GREAT BARRIER REEF MARINE PARK AUTHORITY

BENTHIC REEF SURVEY — DATA SHEET — MANTA TOWS

Reef Name ____ No. ____ Observer Name ____ No. ____ Date / / Times : Tow No. ____

Site Desc'n	reef top	reef crest				
Site No.	1	2				
Aesthetics, 1-6						
Slope, 0-6						
Substrate/Sediment: Mud						
Sand						
Gravel						
Stag Rubble						
Sm. Blocks <50cm						
Lg. Blocks >50cm						
Platform						
Depth, ft						
Cover: Hard Coral						
Soft Coral						
Dead Stand Hard Coral						
Macro Algae						
Colony Size, 1-3						
Diversity, 1-4						
V.P.O.'s						
Benthos Code with						
% hard coral, 1-6						
% soft coral, 1-6						
% other, 1-6						

Code	%
0	0
1	1-5
2	5-15
3	15-30
4	30-50
5	50-75
6	75-100

GREAT BARRIER REEF MARINE PARK AUTHORITY

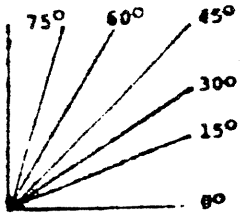
SHEET for MANTA TOW SURVEY.

AESTHETICS

code	
1	N.S.
2	POOR
3	AVERAGE
4	GOOD
5	VERY GOOD
6	OUTSTANDING

SLOPE

code	Slope
0	Flat
1	0-15
2	15-30
3	30-45
4	45-60
5	60-75
6	75-90



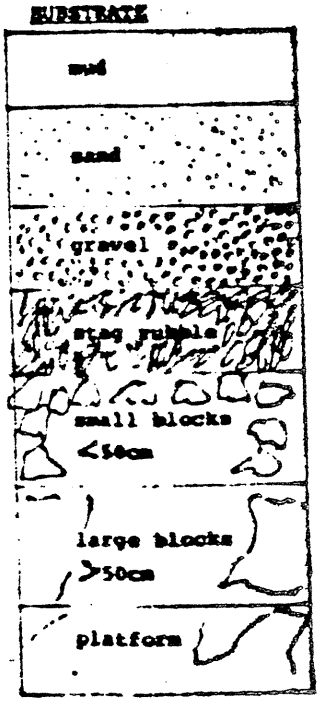
PERCENTAGES

code	%
0	0
1	1-5
2	5-15
3	15-30
4	30-50
5	50-75
6	75-100

DIVERSITY

code	Diversity
1	monoculture
2	Low
3	Medium

SUBSTRATE



PERCENTAGES

code	%
0	0
1	1-5
2	5-15
3	15-30
4	30-50
5	50-75
6	75-100

GREAT BARRIER REEF MARINE PARK AUTHORITY

BENTHIC REEF SURVEY — DATA SHEET — MANTA TOWS

Reef Name ____ No. ____ Observer Name ____ No. ____ Date / / Times : Tow No. ____

Site Desc'n	reef top	reef crest				
Site No.	1	2				
Aesthetics, 1-6						
Slope, 0-6						
Substrate/Sediment: Mud						
Sand						
Gravel						
Stag Rubble						
Sm. Blocks <50cm						
Lg. Blocks >50cm						
Platform						
Depth, ft						
COVER: Hard Coral						
Soft Coral						
Dead Stand Hard Coral						
Macro Algae						
Colony Size, 1-3						
Diversity, 1-4						
C.O.T. Number						
Grouping						
Scars						
V.D.O.S						
Benthos Code with						
% hard coral, 1-6						
% soft coral, 1-6						
% other, 1-6						

Code	%
0	0
1	1-5
2	5-15
3	15-30
4	30-50
5	50-75
6	75-100

GREAT BARRIER REEF MARINE PARK AUTHORITY

SHEET for MANTA TOW SURVEY.

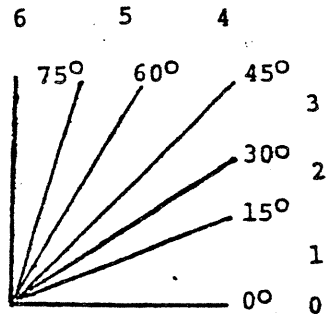
1 AESTHETICS

code

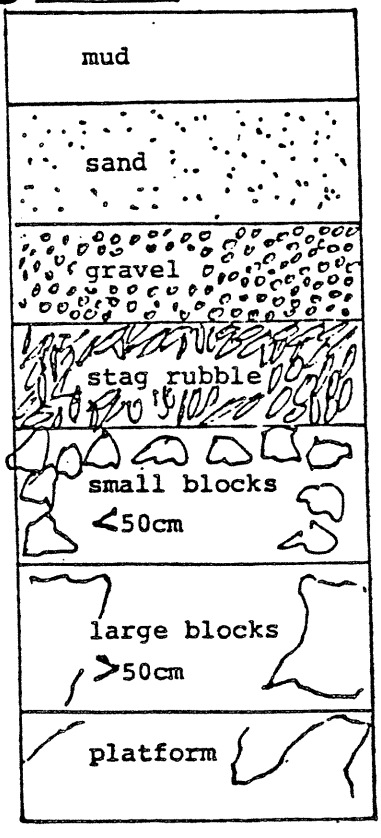
1	R.S.
2	POOR
3	AVERAGE
4	GOOD
5	VERY GOOD
6	OUTSTANDING

2 SLOPE

code



3 SUBSTRATE



4 Depth (Range in feet).

5 Hard, Soft, Dead Standing

Hard and Macro Algae

(% Cover of colonizeable substrate).

6

COLONY SIZE		PERCENTAGES	
1	SMALL	code	%
2	MEDIUM	0	0
3	LARGE	1	1-5
		2	5-15
		3	15-30
		4	30-50
		5	50-75
		6	75-100

7 DIVERSITY

code	Diversity
1	monoculture
2	Low
3	Medium
4	High

8 C.O.T. NUMBER

0	NONE
1	1-10
2	11-100
3	101+

9 C.O.T. GROUPING

0	NONE
1	Together
2	Uniformly Scattered

10 FEEDING SCARS

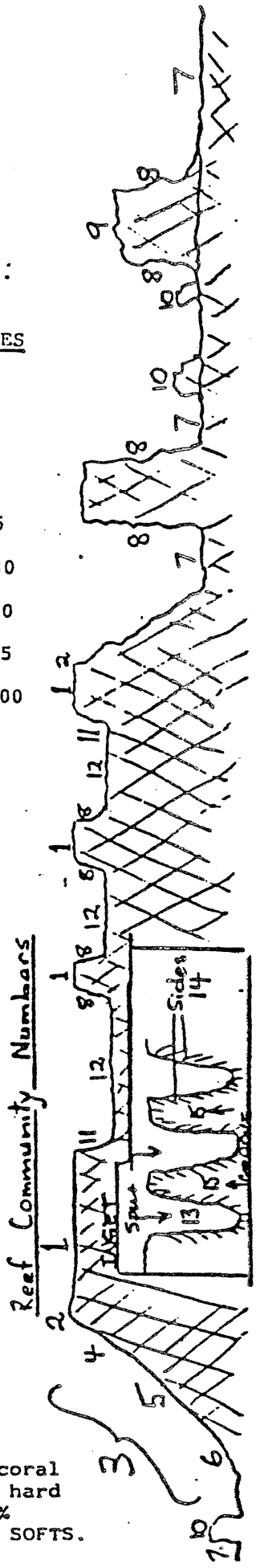
0	NONE
1	1-10
2	11-100
3	101+

11

V.D.O.'s

Growth form and % of hard coral or soft coral cover e.g. 310-6 = 310 is 75-100% of the hard coral coral cover which may only be 5-15%

DO NOT RECORD MORE THAN SIX HARDS OR SIX SOFTS.



APPENDIX II

INNISFAIL TO LIZARD ISLAND MANTA TOW SURVEY

BENTHIC AND CROWN OF THORNS SURVEY

12TH MARCH - 29TH MAY 1980.

Five transects containing 61 reefs, islands and shoals (see attached map) were visited during five ten day expeditions on the TSMV "Hero".

Field Personnel

Four temporary staff were hired, trained during a week long trip to Britomart and then completed five ten day trips. These staff were:

Warwick Nash - Field coordinator
John Robertson)
Michael Haywood) Field observers
Michael Osmond)

Permanent staff participants included:

Wendy Craik - 7 days
Chris Smalley - 4 days
Garry Watkins - 6 days
Len Zell - 18 days plus training trip.

During the period 24th - 27th May (incl.) a group from CSIRO Canberra were also on board carrying out Landsat ground truth studies of reflectance, temperature and salinity in the Arlington Reef Area. This team consisted of:

Dr David Jupp
Kevin Mayo
Stuart Kendall
Sandra Witts

Unfortunately Dr Jupp was injured their second day out and returned to Canberra. The rest of the team remained on board and completed the data collection on Arlington. They were then left on Green Island to carry out further work there, in cooperation with Debbie Kuchler of the Geography Dept. James Cook University.

The "Hero" crew consisted of:

Cecil Watkins	Captain
Neville Wilke	Deckhand and cook
Colin Dove	Deckhand and cook

../2

Conditions

Weather throughout was quite variable ranging from periods of 30 knot southeasterlies to periods of dead calm. The field team lost one and a half days due to unworkable weather. Generally back reef areas were worked during rough seas. If the seas were moderate, reef fronts were worked only during high tide periods or if it was considered safe.

A Zodiac MK III Grand Raid with twin 15HP outboards were used throughout. The boat gave excellent service with some minor repairs necessary in the field. The twin motors supplied excellent service and safety backup.

Contact with "Hero" was maintained using a 27 Mhz marine radio handset with the same frequencies as the set on the Hero.

The TSMV "Hero" was an excellent boat to work from with the lack of a duckboard making loading and unloading of the dinghy difficult at times. The crews must be given the highest praise for their continuous support of the field team at all times.

Support from staff in the office arranging cars, purchasing equipment and carrying out many and varied requests was excellent.

Work Completed

Sixty one reefs, islands and shoals were listed for mapping (from B&W 16,200' aerial photographs) after examination of the James Cook University 14°-17°S chart and the Queensland Lands Department Strip Map of the Great Barrier Reef. See attached maps showing reefs mentioned in the report.

Reefs, Islands and Shoals are tabled as follows:

C - completed (manta tows around whole reef)
PC - partially completed (part of reef towed)
Y - yet to be done
I - impossible to survey - too deep or visibility remains too poor or reef too small.
(x) - Number of tows completed on that reef.

Townsville Transect

Britomart Reef	TV01	Completed during and after training	(50)

Innisfail Transect

Ellison Rf.	IF01	C	(20)
Feather Rf.	IF02	C	(14)
Cayley Rf.	IF03	C	(16)
Wardle Rf.	IF04	C	(14)
Peart Rf.	IF05	C	(11)
Howie Rf.	IF06	C	(23)
		TOTAL	(98)

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Cairns Transect

Green Island	CN01	C	(9)
Arlington Rf.	CN02	C	(44)+(64 tes tows)
Upolu Cay Rf.	CN03	C	(8)
Middle Cay Rf. (Little Upolu)	CN04	C	(7)
Oyster Rf.	CN05	C	(8)
Michaelmas Rf.	CN06	C	(23)
Hastings Rf.	CN07	C	(13)
		TOTAL	176

Port Douglas Transect

Batt Rf.	PD01	PC	(3)
Tongue Rf.	PD02	PC	(23)
Low Isles	PD03	Completed previous to this trip	(5)
8T Rf.	PD04	C	(6)
9P Rf.	PD05	PC	(4)
Opal Rf.	PD06	Y	-
		TOTAL	41

Cooktown Transect

N°3 Ribbon Rf.	CK01	C	(11)
14 Li Rf.	CK02	C	(5)
16 T Rf.	CK03	C	(4)
Egret Rf.	CK04	C	(8)
13 L Rf.	CK05	C	(6)
10 T Rf.	CK06	C	(15)
N°4 Ribbon Rf.	CK07	C	(9)
12 P Rf.	CK08	C	(3)
11 P Rf.	CK09	C	(6)
Boulder Rf.	CK10	C	(8)
9 R Rf.	CK11	C	(5)
8 R Rf.	CK12	C	(4)
N°5 Ribbon Rf.	CK13	C	(10)
Williamson Rf.	CK14	C	(14)
6 R Rf.	CK15	C	(1)
7 P Rf.	CK16	Y	-
		TOTAL	109

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Lizard Island Transect.

Fourfoot Rock	LZ01	C	(1)
Decapolis Rf.	LZ02	I	-
30 P Rf.	LZ03	I	-
Sim Rf.	LZ04	I	-
29 P Rf.	LZ05	I	-
Maxwell Ra.	LZ06	I	-
Linnet Rf.	LZ07	C	(3)
Martin Rf.	LZ08	C	(7)
Turtle Group I	LZ09	C	(2)
" " II	LZ10	C	(3)
" " III	LZ11	C	(1)
" " IV	LZ12	C	(2)
" " V	LZ13	C	(2)
" " VI	LZ25	Y	-
Turtle Rf.	LZ14	C	(1)
Eyrie Rf.	LZ15	C	(14)
Lizard Island	LZ16	C	(18)
Nymph Island	LZ17	C	(4)
MacGillivray Cay Rf.	LZ18	C	(2)
Petricola Shoal	LZ19	I	-
Stewart Shoal	LZ20	I	-
Underwood Shoal	LZ21	I	-
Carter Rf.	LZ22	C	(14)
Day Rf.	LZ23	C	(20)
Hicks Rf.	LZ24	C	(18)
		TOTAL	112

In all, including the 50 Britomart Reef Survey tows, 586 individual tow debriefs were recorded for purpose of data analysis. Training tows have not been recorded but would be in the order of 30-40.

Some fifty scuba dives were undertaken for the purposes of training (for manta tows), data recording, specimen collection, coral trout survey and photography.

Photographic work collected a wide selection of material covering -

- Crown of thorns infestations, damage and individuals hiding, feeding, etc.
- marine plants during night and day
- marine animals during night and day
- divers at work
- laying of transects
- planning daily activities
- cays
- intertidal species on reef boulders and cays
- ships and trawlers
- Cairns harbour
- scientists at work
- reef communities.

Data Treatments

Crown of Thorns

A separate report is being prepared by Mr Nash. This report discusses the numbers of Crown of Thorns found, reefs where they occurred, reefs with obvious and apparent damage.

Also 230 starfish were collected for size measurement, sexing and electrophoretic studies of the pyloric caeca. This electrophoresis work is being done by Mr Nash as a part of his M.Sc. degree at James Cook University. Results will be readily available to the Authority should we need them.

Benthic Studies Results

The manta tow observers were debriefed using the standard computor data sheet. Training in the technique was found very easy due to the keeness and ability of the team and also the use of the Coral Identikit set. The observers were yielding fair results after two days of intensive towing and scuba diving training. Constant reference was made to the Identikit set until each category was familiar. During the last two or three ten day expeditions the observers were seldom referring to the Identikit and even the "crib sheet" which gives the codes for % cover, substrate, slope, aesthetics etc.

The data collected has been organised into transect groups, checked and copied so a duplicate set is available for working purposes and security if one is lost. This information now awaits punching into the computor program and subsequent mapping and collation.

Echosounding Work

Cook's Passage, One Mile and Half Mile Openings were systematicall surveyed using the "Hero" and a Furuno FG 200 echosounder. These passages now have relatively accurate bathymetric charts giving some idea of their relationship to the nearby reefs and possibly history (refer to Veron's work published as a result of the 1973 University of Queensland and Royal Society G.B.R. Expedition)

The result of this work will be presented later in a brief report with maps.

People/Organisations Contacted

Lizard Island Resort - discussions were held with Mr Moss Hunt the manager. The Zoning Plan for Capricornia was discussed. He was also advised of the Authority's plan to declare the Innisfail Lizard Island Section soon. (L Zell)

Lizard Island Research Station - discussed Zoning Plan for Capricornia and proposed Innisfail Lizard Island Section, operators of the Authority's Running Free boat and motors, the new Research Station catamaran, sailing research vessel. The Hero also picked up and delivered some 2,500 litres of diesoline to the station saving them several hundred dollars at no cost nor great inconvenience to the Hero. Thanks must be given to the skipper here for his co-operation.

ABC Nationwide - Mr Nash gave a short interview to Gary Neat re the techniques to control Crown of Thorns and some information on populations in that area. The program was shown in early June.

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Queensland Fisheries Service - Q.F.S. were kept informed of the expeditions movements during all trips. Unfortunately Dr Bob Pearson was unable to participate because of other commitments. At Green Island the QFS collection team and the GBRMPA team were able to co-operate in location of populations and discuss techniques.

Discussion - The whole program ran smoothly due to the excellent support from the Hero crew, Townsville office backup and most importantly the excellent interest and application shown by the four man field team. Considering the weather conditions the results are excellent.

Recommendations

1. The Zodiacs have air-sea rescue orange painted down each side making them more visible at distance.

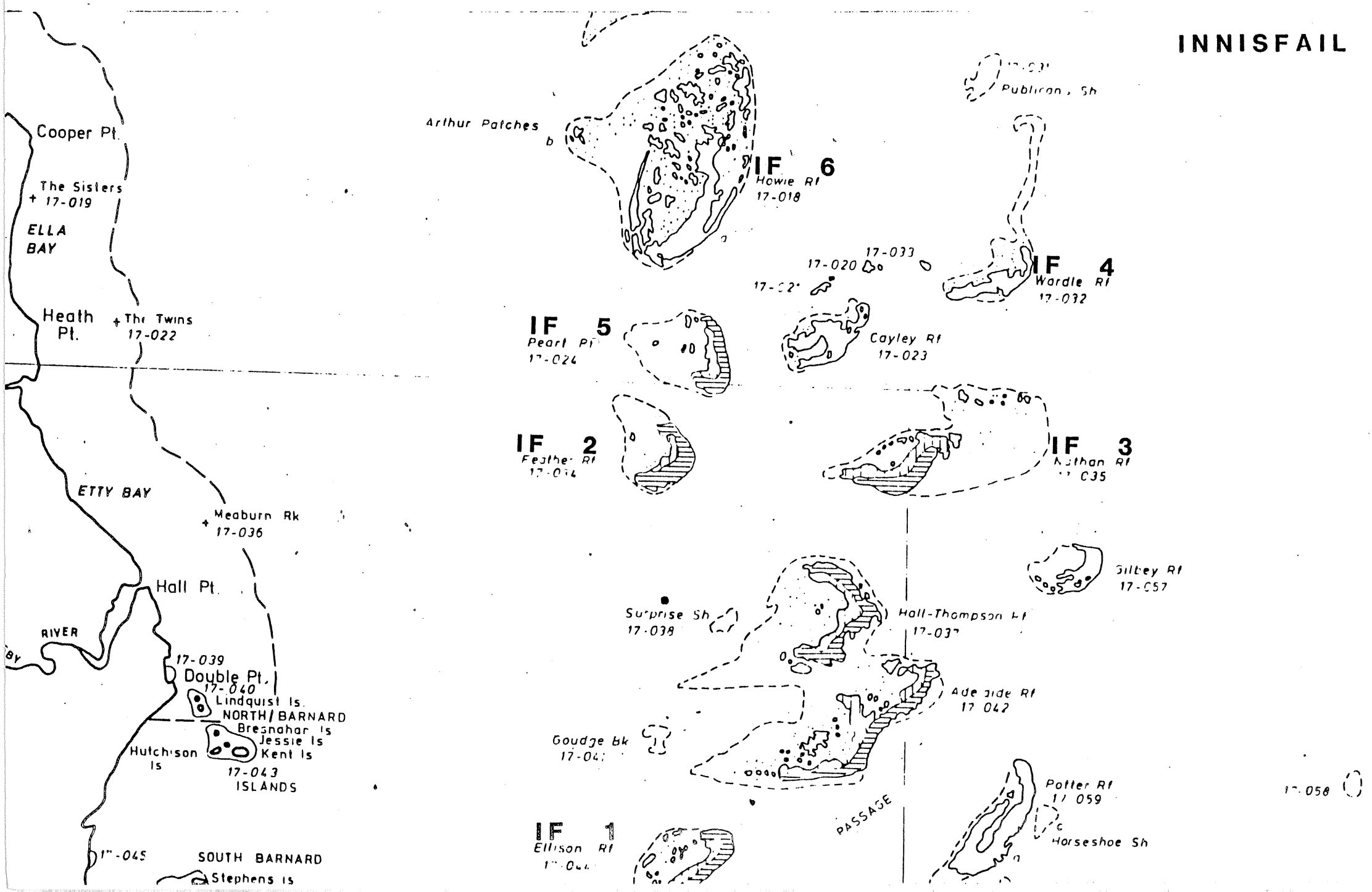
2. That the data be processed as soon as possible preferably by hiring some of the field team to do the work. Their infield familiarity with the data is invaluable.

3. That a series of similar transects be considered for the whole of the Great Barrier Reef.

4. The Authority consider, if 3. is implemented, long term charter of the Hero. If this was done minor modifications can be requested and the vessel can also be utilized for use by other survey work being carried out by and for the Authority.

(L.D.Zell)
Marine Park Officer

11/6/80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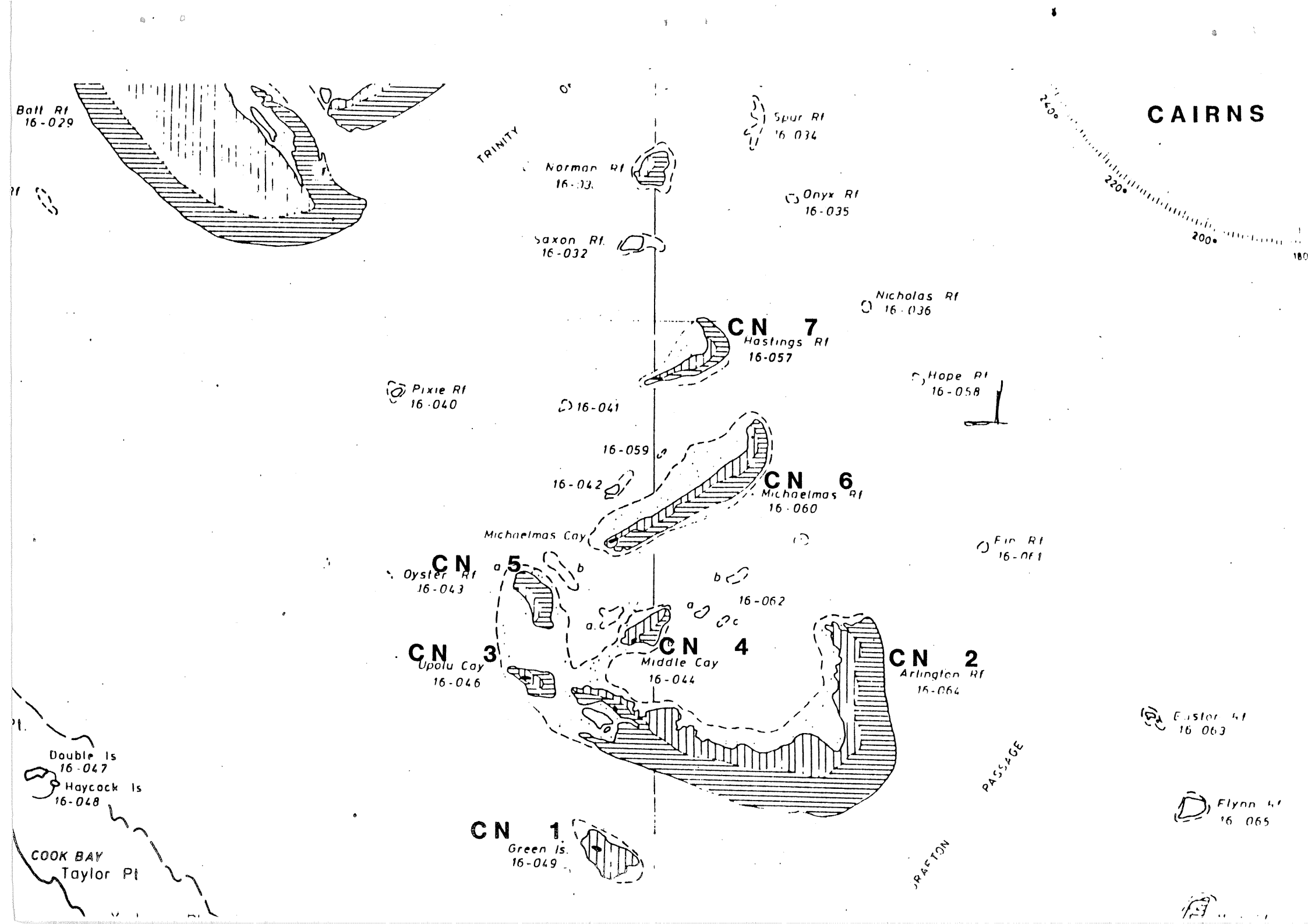
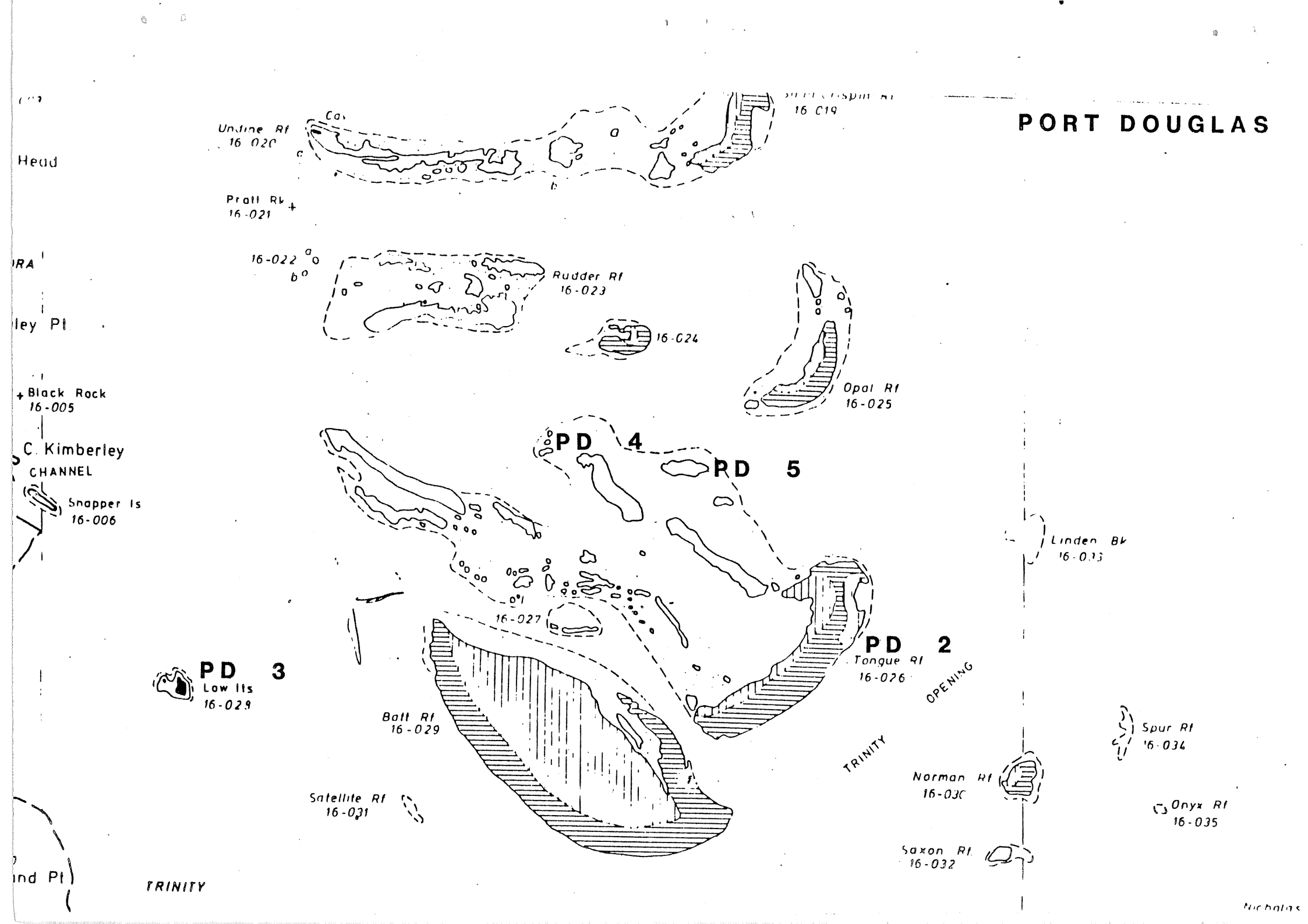
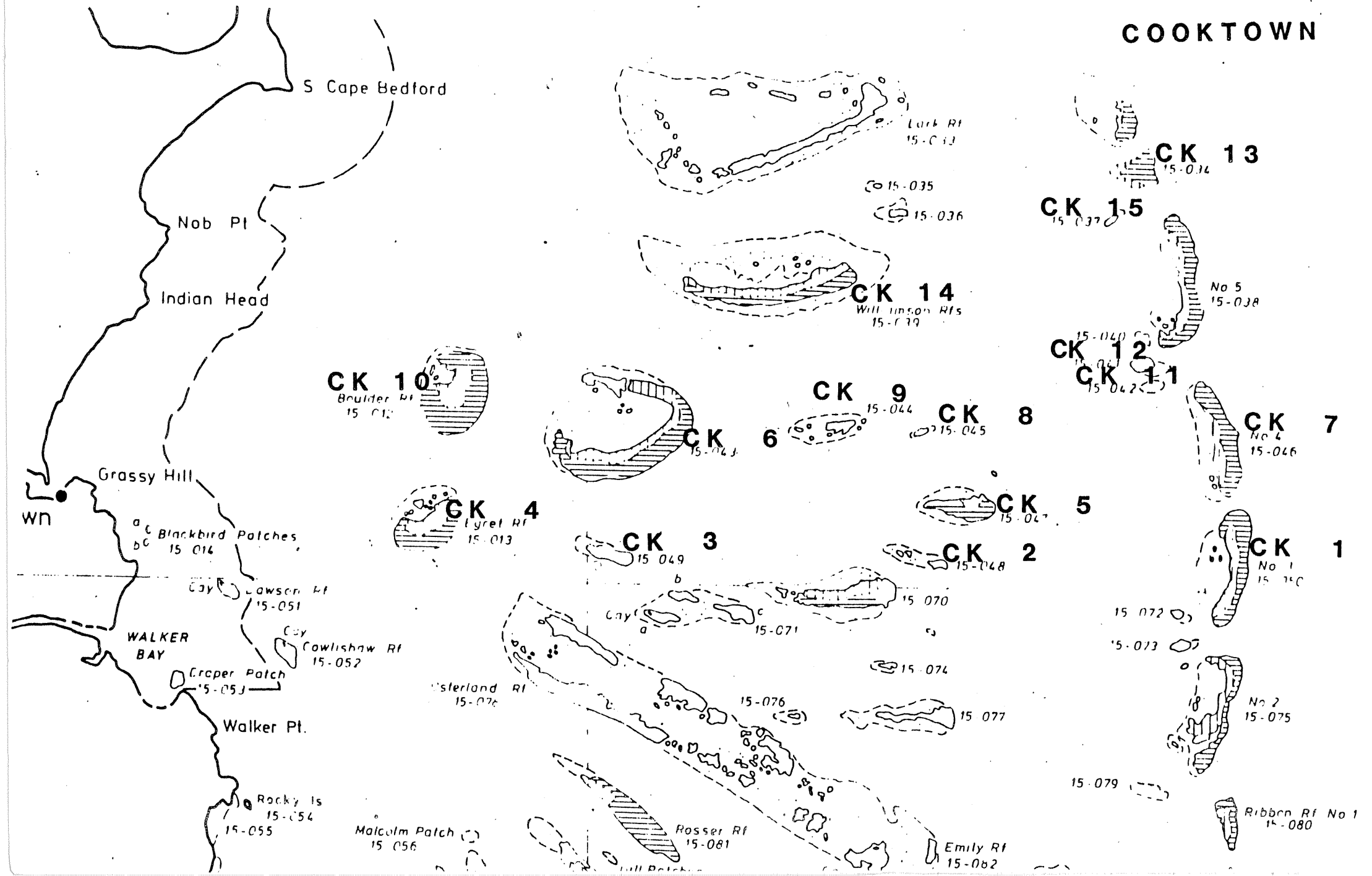
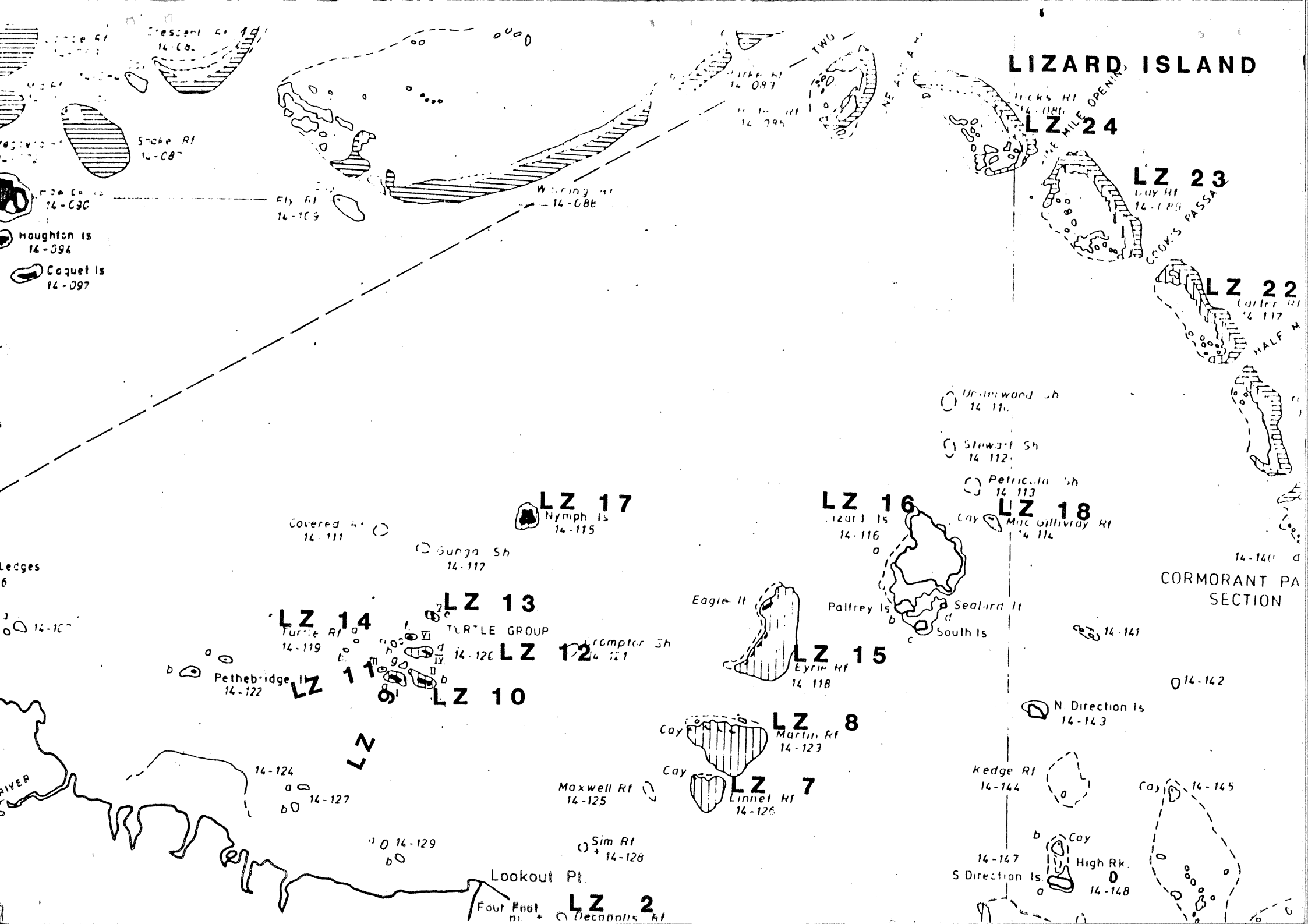
Cooper Pt
The Sisters
17-019
ELLA
BAY
Heath
Pt.
The Twins
17-022
ETTY BAY
Meaburn Rk
17-036
Hall Pt
RIVER
17-039
Double Pt.
17-040
Lindquist Is.
NORTH BARNARD
Bresnahan Is
Jessie Is
Hutchison
Is
Kent Is
17-043
ISLANDS
17-045
SOUTH BARNARD
Stephens Is
Arthur Patches
IF 6
Howie Rf
17-018
Publican Sh
17-031
17-033
17-020
17-032
IF 4
Wardle Rf
17-032
IF 5
Peart Pf
17-024
Cayley Rf
17-023
IF 2
Feather Rf
17-034
IF 3
Nathan Rf
17-035
Gilbey Rf
17-057
Surprise Sh
17-038
Hall-Thompson Rf
17-037
Adelaide Rf
17-042
Goudge Bk
17-041
PASSAGE
IF 1
Ellison Rf
17-044
Potter Rf
17-059
Horseshoe Sh
17-058


CAIRNS
Batt Rf
16-029
TRINITY
Norman Rf
16-033
Spur Rf
16-034
Onyx Rf
16-035
Saxon Rf
16-032
Nicholas Rf
16-036
CN 7
Hastings Rf
16-057
Pixie Rf
16-040
16-041
Hope Rf
16-058
16-059
16-042
CN 6
Michaelmas Rf
16-060
Michaelmas Cay
CN 5
Oyster Rf
16-043
16-062
CN 4
Middle Cay
16-044
CN 3
Upolu Cay
16-046
CN 2
Arlington Rf
16-064
CN 1
Green Is.
16-049
Double Is
16-047
Haycock Is
16-048
COOK BAY
Taylor Pt
PASSAGE
Flynn Rf
16-065


PORT DOUGLAS
Undine Rf
16 020
Pratt Rf
16-021
16-022
Rudder Rf
16-023
16-024
Opal Rf
16-025
16 C19
Head
Black Rock
16-005
C. Kimberley
CHANNEL
Snapper Is
16-006
PD 4
RD 5
16-027
PD 3
Low Its
16-029
Ball Rf
16-029
PD 2
Tongue Rf
16-026
OPENING
Linden Bk
16-033
Spur Rf
16-034
TRINITY
Norman Rf
16-030
Onyx Rf
16-035
Satellite Rf
16-031
Saxon Rf
16-032
TRINITY


COOKTOWN
S Cape Bedford
Nob Pt
Indian Head
Grassy Hill
WN
WALKER BAY
Walker Pt.
Blackbird Patches
15-014
Lawson Rf
15-051
Cay
Cowlishaw Rf
15-052
Cay
Cooper Patch
15-053
Rocky Is
15-054
15-055
Malcolm Patch
15-056
Lark Rf
15-033
15-035
15-036
CK 14
Will Jinson Rfs
15-039
CK 13
15-034
CK 15
15-037
No 5
15-038
15-040
CK 12
CK 11
15-042
CK 10
Boulder Rf
15-012
CK 9
15-044
CK 8
15-045
CK 6
15-043
CK 7
No 4
15-046
CK 4
Tyret Rf
15-013
CK 5
15-047
CK 3
15-049
CK 2
15-048
CK 1
No 1
15-070
15-071
15-072
15-073
15-074
15-076
15-077
No 2
15-075
15-079
Ribbon Rf No 1
15-080
Rosser Rf
15-081
Emily Rf
15-082


LIZARD ISLAND
LZ 24
LZ 23
LZ 22
LZ 17
Nymph Is
14-115
LZ 16
LZ 18
LZ 13
TURTLE GROUP
LZ 14
LZ 12
LZ 11
LZ 10
LZ 15
LZ 8
LZ 7
LZ 2
Houghton Is
14-096
Coquet Is
14-097
Fly Rf
14-109
Eagle It
Palfrey Is
South Is
Seaford It
Eyrie Rf
14-118
Martin Rf
14-123
Linnet Rf
14-126
Maxwell Rf
14-125
Sim Rf
14-128
Pethebridge It
14-122
Turtle Rf
14-119
Lookout Pt
Four Foot
N. Direction Is
14-143
S Direction Is
14-147
High Rk
14-148
Kedge Rf
14-144
CORMORANT PA
SECTION
Ledges
RIVER

574.072
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1984

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