Coumbis (1988)

REMOTE SENSING COMPONENT

OF

THE RELATIONSHIP BETWEEN *Acanthaster* OUTBREAKS

AND

WATER MASS CHARACTERISTICS

IN

THE GREAT BARRIER REEF MARINE PARK

INTERIM REPORT

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INTRODUCTION

The Great Barrier Reef covers an area of some 344,000 km^2 off the NE coast of Australia. It consists of many reef systems, of which about 30% have been subjected to the presence of Acanthaster planci (Crown-of-Thorns starfish) over recent years. Selected reefs have experienced mild to severe effects. This management problem has given impetus to an extensive research programme, involving the Great Barrier Reef Marine Park Authority (GBRMPA) in collaboration with other institutions and individuals. In order to gain a synoptic view, remotely sensed data has been required, as part of this programme.

This paper examines the remote sensing component of the project: "The Relationship between Acanthaster outbreaks and water mass characteristics in the Great Barrier Reef", which tests the hypothesis that the Crown-of-Thorns starfish breeding grounds may be associated with areas of high productivity - as indicated by chlorophyll "a" or phytoplankton distribution.

AIM OF THE STUDY

To delineate and map the extent of biologically productive areas in the Great Barrier Reef region using Coastal Zone Colour Scanner (CZCS) data, and relate this to the pattern of outbreaks of Acanthaster planci.

METHODOLOGY

Digital image processing of Coastal Zone Colour Scanner (CZCS) data was performed within GBRMPA's Digital Mapping Facility using the microBRIAN package on an IBM AT compatible computer (see Table One). Several menu options of the microBRIAN system were utilized for this project.

TABLE ONE

CZCS DATE PARAMETERS

IMAGE NO.	ORBIT NO.	DATE
^0112	4932	16th October 1979
^0113	4932	16th October 1979
^0114	4932	16th October 1979
^0421	5512	27th November 1979
^0721	7281	3rd April 1980
^1231	9506	11th September 1980
^1711	11966	8th March 1981
^2021	10957	25th December 1980
^2022	10957	25th December 1980
^2231	17840	7th May 1982
^2411	17895	11th May 1982
^2431	19858	30th September 1982

Satellite Data

The CZCS on board the Nimbus 7 satellite, an experimental one, is the first spacecraft instrument constructed primarily for measurement of ocean colour, and use over water. Resolution is 825 x 825m, and the useful swath width is approximately 1600 km. There are six spectral bands (see Table 1) - five sense backscattered solar radiance (visible light), and the sixth senses emitted thermal radiance. The first four bands are very specific and sensitive, being only 20nm wide. The fifth band is wider, approximating the spectral response of Channel 6 in the Landsat MSS, which is useful in delineating land, clouds and sea (Hovis et al, n.d.; Carpenter, 1982).

TABLE TWO

Performance Parameters	Channels					
	1	2	3	4	5	6
Scientific Observation	Chlorophyll Absorption	Chlorophyll Correlation	Yellow Stuff	Chlorophyll Absorption	Surface Vegetation	Surface Temperature
Center Wavelength λ Micrometers	0.443 (blue)	0.520 (green)	0.550 (yellow)	0.670 (red)	0.750 (far red)	11.5 (infrared)
Spectral Bandwidth Δλ Micrometers	0.433 – 0.453	0.510 – 0.530	0.540 – 0.560	0.660 – 0.680	0.700 – 0.800	10.5 – 12.5
Instantaneous Field of View (IFOV)	← 0.865 x 0.865 Milliradians (0.825 x 0.825 km at sea level) →					
Co-registration at NADIR	<0.15 Milliradians					
Accuracy of Viewing Position Information at NADIR	<2.0 Milliradians					
Signal to Noise Ratio (min.) at Radiance Input N < (mW/cm² · STER · μm)	>150 at 5.41	>140 at 3.50	>125 at 2.86	>100 at 1.34	>100 at 10.8	NETD of 0.220°K at 270°K
Consecutive Scan Overlap	25%					
Modulation Transfer Function (MTF)	1 at 150 km target size, 0.35 min. at 0.825 km target size					

(After Hovis, n.d.)

Subsetting

Each image was spectrally subsetted into two different images, as the microBRIAN has a four channel limit and the CZCS has six bands. The naming convention used for each image or subset refers to the CCT of origin, file number on the CCT (usually 1-3), subset number, and stage of processing. Channels 1, 2, 3 and 4 were used in the later analyses.

Masking

As this project concentrated entirely on the Great Barrier Reef and surrounding waters, land and cloud were therefore irrelevant to the final analysis. CZCS Channel 5 was used to determine the cut-off point to remove the land/cloud data from each image.

Noise Removal

A full weighted smoothing operation using a 3 x 3 neighbourhood, was applied to the images to remove noise and spikes in the data. Where data lines were affected by the absence of one or more channels, the median neighbouring pixel treatment was applied.

Data Normalization

Histogram equalization or normalization was performed on all images. This enabled standardization of the data set for later comparisons.

Radiance Correction

Waters of the Great Barrier Reef region are often turbid. Therefore the removal of path radiance from the data, using the Gordon method (Gordon, 1978; Gordon et al, 1980) which assumes clear water conditions, was considered to be not valid for this project. An approximation of this method, the darkest pixel correction method, was used in this study as a first order correction to the data.

Channel Ratios

A ratio of CZCS Channel 3 (sensitive to oceanic upwelling irradiance) over CZCS Channel 1 (very sensitive to chlorophyll "a" concentrations) was used to detect plankton-rich waters.

Classification

The percentage distribution for the whole set of channels 1, 2, 3 and 3/1 was derived, and used to delineate the class themes, which were then classified and mapped into different chlorophyll "a" levels. At present, these maps consist of eight classed which are colour coded as follows:

Dark Green	-	very high chlorophyll "a" levels
Red	-	high
Orange)		
Yellow)		
Light Green)	-	medium
Beige)		
Blue	-	low
Pink	-	very low

RESULTS

In the first initial results, the best of nine relatively cloud-free images, out of a total of thirty-three, have been used to map the productivity levels within the marine park.

Several reefs occur in areas of high to very high plankton-rich waters. In the Far Northern section, they occur on the eastern side of the ribbon reefs, north of Triangle reef and on the eastern side of the reefs between Wreck Bay and Tijou reef. In the Cairns Section they occur between Port Douglas and the Mulgrave River, Low Isles, Batt, Arlington, Moore, Sudbury and Maori Reefs. Those east of Hinchinbrook Island, the Palm Islands Group and Hydrographers Passage, Britomart, Trunk, The Slashers and Davies Reefs are areas of plankton rich waters in the Central Section.

The waters offshore between Port Douglas and Mackay; those covering the shoal area west of Triangle Reef; and those within the Capricorn Channel are the richest plankton waters within the whole Great Barrier Reef Marine Park.

Medium to moderate phytoplankton concentrations are the most common and generally occur within the central lagoon area inside the barrier reefs. In the Far Northern Section of the marine park, they also occur around the ribbon reefs, while in the Cairns Section, they occur around all reefs south of Endeavour Reef.

Low and very low nutrient waters generally occur within the coastal zone. In the Far Northern Section of the marine park they occur around inshore reefs, while in the Cairns Section they occur around all reefs, north of Endeavour Reef.

CONCLUSION

The first phase of the project is now complete. The images have now been submitted to oceanographers to assess their significance regarding Crown of Thorns Starfish outbreaks.

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Choat + McCormick (1988)

INTERIM REPORT

THE INDIRECT EFFECTS OF *ACANTHASTER* AND HUMAN DISTURBANCE ON FISH ABUNDANCE PATTERNS AT GREEN ISLAND: A PRELIMINARY EXAMINATION

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INDIRECT EFFECTS OF *ACANTHASTER* AND HUMAN DISTURBANCE ON FISH ABUNDANCE PATTERNS AT GREEN ISLAND: A PRELIMINARY EXAMINATION

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PREAMBLE

The wide variety of natural and man-made disturbances to the reef-associated fauna, makes Green Island unique on the Great Barrier Reef. Green Island has been subject to two major infestations of *Acanthaster planci* in the last 25 years. This has greatly modified the coral community, and may be largely responsible for the present low coral cover. Furthermore, its value as a tourist destination has resulted in an unnaturally high nutrient loading, together with a change in the sediment profile of the reef. This stems from the outflow of concentrated sewerage over the reef flat and land retention. Recent research suggests that the interaction of these biological and man-induced disturbances on the reef environment have resulted in the development of an extensive seagrass system. This now extends over more than 13 hectares of reef. This bed is a unique feature in itself, occurring not only on an offshore island but also over a coral bommie field.

Research that has examined the effects of *Acanthaster* and its potential influence on fish communities have suggested two likely effects:

(1) a decline in the abundance of some fish species in the wake of *Acanthaster* disturbances, particularly coral obligates;

(2) an increase in the herbivorous fishes, as macroalgae colonizes the dead coral.

Examination of the temporal changes in the patterns of fish distribution over a wide range of habitats and levels of *Acanthaster* damage can investigate these suggestions.

This report is a preliminary examination of the distribution of reef fish at Green Island with respect to the effects of *Acanthaster* damage. The extent and nature of the seagrass bed requires that it is incorporated into the sampling design. Patterns of fish abundance were investigated over areas of reef and seagrass. Furthermore, due to the unique nature of the Green Island reef environment monitoring sites were established on Arlington Reef, 2.2 nm NNE of Green Island. This allows a valuable comparison of trends in the distribution patterns of fish over time, with an area not affected by the same level of *Acanthaster* damage or nutrient loading. This sampling design was the best compromise between a study to assess, in general, the effects of *Acanthaster* damage on fish populations, and one to examine the effects specifically at Green Island. Detailed benthic information was collected to enable the examination of relationships between fish and the sessile fauna. In addition, the densities and the distribution of *Acanthaster* and sea urchins was recorded. Sampling sites were established for long-term monitoring of both adult and juvenile reef fish populations. The specific aims of the study were four-fold:

(1) To examine the fish fauna on and around coral bommies within a seagrass bed at Green Island, and determine whether it differed from a similar area outside the seagrass bed, or on a neighbouring reef.

(2) To investigate whether the distribution patterns of fish found could be explained by differences in sessile fauna on the bommies, or the presence of *Acanthaster*, rather than presence of the seagrass bed.

(3) To examine patterns in the recruitment of reef fish within and outside the Green Island seagrass beds.

(4) To examine the distribution patterns of *Acanthaster planci* and sea urchins in relation to the seagrass beds and other sessile fauna.

Having fulfilled the objectives of the initial proposal, results to date were intriguing enough to warrant this interim report and expression of interest in the further monitoring of Green Island fish populations.

Study Site

Green Island is a vegetated sand cay located on the inner Great Barrier Reef, 27km northeast of Cairns. It is surrounded by some 1200ha of reef. The reef is classified as a lagoonal platform reef, although the lagoon to the north of Green Island is shallow and not marked. A large reef flat extends 1.5km east, and 0.75km to the north of the sand cay. An extensive system of seagrass beds surround most of the cay, being densest to the north. This bed is composed of predominantly the seagrasses *Thalassia hemprichii* and *Halodule uninervis*. Unlike coastal meadows, coral bommies are scattered throughout this seagrass bed.

Arlington Reef lies 2.2 nm NNE of Green Island. Sampling was undertaken on bommies within the western lagoon. This was chosen as the area on the reef most similar in exposure and structure to the Green Island backreef study area. No seagrass bed was present.

METHODS

Study Organisms

The emphasis of the study was to obtain a precise estimate of the distribution patterns of reef fish populations in the study sites. Of secondary importance was the quantification of sessile fauna. Methodology reflects this emphasis. Target organisms can be split into four groups on the basis of sampling methodology.

(1) **Fish:** rare or highly mobile e.g. scarids, acanthurids, siganids, lethrinids and lutjanids.

(2) **Fish:** common and territorial e.g. pomacentrids, chaetodontids, labrids and newly recruited fish.

(3) **Sessile Fauna** such as hard and soft corals, sponges, macroalgae, gorgonians and hydroids.

(4) ***Acanthaster* and sea urchins**

General Design

Emphasis was placed on the intensive sampling of the Green Island reef fauna and secondarily on a comparative area on Arlington Reef. At Green Island, the main seagrass bed on the backreef was divided arbitrarily into two sampling sites. Within each site the fish and sessile fauna on five coral bommies of similar size were sampled. Similarly, two sites within an area of similar exposure and depth were chosen for a comparison. Five bommies were sampled within each site (see Fig 1). In addition, five counts of the fish fauna around the **base of the bommies** were made within the seagrass and non-seagrass area. Five fish counts were also made over the seagrass away from bommies, and over the sand away from the bommies in the non-seagrass area. Figure 1 shows the position of all bommies and sites sampled.

For comparison, six bommies within two sites on the western backreef of Arlington Reef were sampled for fish and sessile fauna. One small and one large strip transect per bommie was swum for fish. Six line-intercept transects per bommie were sampled for the sessile fauna.

Specific Methodology

(1) Rare or highly mobile fish

One 20 x 10m visual strip transect was positioned on the top of each target bommie. The diver laid a 20m tape and slowly swam recording fish within one 5m lane at a time. Fish were identified to species.

(2) Common and territorial fish

One 20 x 4m visual strip transect was positioned along the same centre tape as the 20 x 10m fish transects. The diver searched each 2m lane in detail. Fish were recorded to species and their densities noted. Additional transects of both sizes were also swum so that the centre tape lay 5m from the edge of the bommies. In the seagrass sites this encompassed both sand and seagrass substratum. Names of the fish of the family Pomacentidae follow Allen (1975).

(3) Sessile Fauna

Sessile organisms and substratum were quantified using 10m line-intercept transects. Two random transects were sampled on the tops of each of the five bommies within the four sites (2 seagrass, 2 non-seagrass). Organisms were placed into broad lifeform categories (e.g. Acropora, Non-Acropora, Massive, Soft coral, Rubble etc.).

In addition, 20m line intercept transects were sampled along the same tape as the bommie fish counts. Organisms were identified to genus where possible. This allowed the densities of fish species to be directly related to the sessile organisms and substratum on which they live. These transects can also be used as additional replicates (making a total of 3 per bommie) to quantify general bommie sessile fauna*.

(4) *Acanthaster* and sea urchins

Densities of starfish and sea urchins were recorded in 10 x 4m strip transects searched in detail. Three transects were sampled on five bommies per site.

RESULTS AND DISCUSSION

There was no evidence of an outbreak or recent damage by *Acanthaster planci* in the backreef region on Green Island, where the sampling was concentrated. Only one *A. planci* was found during the sixty strip transects sampled. Monitoring the sites established will allow changes in *Acanthaster* densities to be related to changes in the benthic and fish fauna. Since there is no *Acanthaster* outbreak its effects on the fish distribution and densities can only be inferred from comparisons between areas and reef affected to varying levels. On Green Island the most obvious feature possibly resulting indirectly from the *Acanthaster* damage in combination with other factors (high nutrient loading) is the development of an extensive seagrass bed. Consequently sampling was concentrated within and outside this bed to determine its effect on fish abundances.

Preliminary analysis suggests that the presence of seagrass has a marked effect on the relative abundance of some species within the reef fish community. This is most apparent in the distribution patterns of the juveniles of a large number of fish families

* Data from 20m line transects can be used in conjunction with 10m transect information, since a longer transect simply yields a more precise estimate of percentage cover of the organisms.

(see Table 1). High densities of newly recruited scarids, siganids, lethrinids, lutjanids and mullids were found to be present in the seagrass beds (see Fig 2). In the case of the lethrinid and mullid juveniles, the seagrass was the only place they were found to occur (Fig 2). These newly recruited fish were not distributed evenly over seagrass, rather being concentrated on the interface between the base of the bommie and beginning of the seagrass bed. This interface took the form of a halo of sand which extended 4 to 7m out from the base of the bommie. Scarids and siganids juveniles formed tight foraging groups at the diffuse bommie edge. Similarly, the lethrinid and lutjanid juveniles (particularly *Lutjanus gibbus*) formed monospecific groups in this area. Young of the year mullids (mainly *Parupeneus barberinoides, P. forskalli* and *P. trifasciatus*) formed large foraging groups with the small labrid *Stethojuilis bandanensis* at the edge of the seagrass bed. This association is probably a function of the increased probability of the labrid encountering food organisms when feeding in areas disturbed by mullid foraging.

Intimately associated with these aggregations of juvenile reef fish at the edge of the seagrass were a number of piscivores. The most prevalent of these was the long slender labrid, *Cheilio inermis*. This predator stayed motionless just above the seagrass blades, approximately 3 or 4m from the sand-seagrass interface, and moved slowly into the *Stethojuilis* and mullid schools to feed.

Although the adult parrotfishes were observed to feed intensively on the seagrass, there was no trend for the most common species, *Scarus rivulatus*, to occur in higher densities in the seagrass (see Table 2). Since these are wide ranging, schooling fish, this pattern does not rule out the possibility of large foraging aggregations being present in the seagrass periodically. The effect of schools of feeding scarids can be devastating on other parts of the reef, and may strongly affect the local distribution of seagrass around bommies. Examination of distribution trends over times of the day and feeding periodicity are required.

Not only is the seagrass bed interesting for its high numbers of juvenile reef fish, but also the relatively common occurrence of generally rare fish species. *Calotomus spinidens*, *C. carolinus* and *Leptoscarus vaigiensis* were all recorded in the seagrass beds and not outside. The first of these has only been recorded once before on the Great Barrier Reef from a seagrass bed in the deeper water between northern reefs. The second is rare and may be found in reef crest and reef base habitats on mid- and outer-shelf reefs, while the third has been recorded from temperate Australian seagrass beds (Choat and Randall 1986).

There was no difference in the fish species-diversity between in and outside the seagrass meadows (88 versus 81 species recorded). Furthermore, for a large number of fish species the presence of the seagrass bed did not appear to affect their distribution pattern. The spatial patterns of the large predator species showed a patchy distribution characteristic of highly mobile and schooling species (see e.g. Lethrinids, Fig 3). Similarly, with the exception of one species, adult territorial fish of the genus *Pomacentrus* were abundant both within and outside the seagrass bed. Densities of *P. taeniometopon*, however, differed significantly between seagrass and non-seagrass areas (Fig 3).

The densities of small territorial species, such as *Pomacentrus taeniometopon*, may be intimately related to the composition of the substratum on which they feed and reproduce. Consequently, the type of substratum may be of more importance than factors related to the presence or absence of the seagrass beds or *Acanthaster* damage. However, for this particular case, and for *Pomacentrus* generally, a visual examination of the trends in the dominant substratum categories showed no obvious relationship (compare Fig 3 to Fig 4). Further analyses will be carried out at a specific level to examine in detail any trends of species composition with substratum composition.

Interestingly, a comparison of the densities of adult reef fish between Green Island and Arlington Reef shows much higher densities of most species at Green Island (compare Fig 3 with Fig 5). This is particularly evident for fish in the commercial families lethrinidae and lutjanidae. No lethrinids were recorded at Arlington, while up to 40 individuals per bommie (mainly *Lethrinus nebulosus*) were counted at Green Island. Similarly, a mean of only 1.6 ($200m^{-2}$) lutjanids were counted at Arlington compared to approximately 10 at Green Island. Densities of *Stethojulis* and *Pomacentrus taeniometopon*, for example, were also much less abundant at Arlington. Furthermore, the diversity of species was also much lower at Arlington than Green Island (65, 88 respectively). Three species of lethrinid or lutjanid were present at in the former compared to ten in the latter. This discrepancy may be due to a consistently higher recruitment within the seagrass beds at Green Island, resulting in a higher number of individuals reaching the adult stage. Further monitoring of recruitment at Green and Arlington Reefs, together with survivorship and growth rate information are required to determine this.

Similar densities of the sea urchins *Diadema* and *Echinothrix* were found on bommies within and outside the seagrass beds at Green Island. Interestingly, by far the highest density of the long-spinned black urchin, *Diadema*, was found in the seagrass area (54 per 40m^2). An unidentified species of urchin was also present soley within the seagrass bed, shrouded in cropped seagrass fronds. On Carribean reefs urchins have been attributed, at least in part, to causing the conspicuous clear halo around bommies (e.g. Randall 1965). Although movement and feeding studies are required, preliminary observation suggest this to be the case at Green Island.

From this preliminary examination of the patterns of abundance of fish and benthic organisms in and outside seagrass meadows, the importance of seagrass in supporting large populations of reef fish recruits has been demonstrated. This is of particular interest since many of these species are of some commercial importance. This study suggests that the high diversity and densities of adult fish may be the result of the disturbance regime particular to Green Island; consisting of a combination of *Acanthaster* damage and high nutrient input. Although other studies have demonstrated high recruitment this for temperate and Carribean waters, this is the first study to do so for a tropical Pacific seagrass system. As yet no study has examined the recruitment patterns of fish within seagrass beds over a long time period. The present study forms an ideal basis from which to monitor changes in the fish community over time, and examine the effect of the disturbance-related seagrass beds on fish populations through a comparison of juvenile growth rates and survivorship.

Proposed Future Research

The high abundance of fish recruits within the unique seagrass habitat, highlights that disturbance to the reef environment can have some unexpected and noteworthy consequences. The Green Island seagrass bed is probably an indirect effect of natural and human disturbance. Further study is warranted due to Green Islands important implications to the management the Great Barrier Reef.

Future research proposed involves the expansion of the above programme to other habitats around the Green Island reef and monitoring of the sites already established. Research will endeavour to meet the following aims:

(1) To monitor trends in the recruitment of reef fish within and outside seagrass beds. This will determine whether recruitment into the seagrass beds is consistently higher than in similar areas without seagrass. Most previous studies have been one-off sampling events, often initially undertaken due to the conspicuous presence of large densities of juvenile fish. Only by monitoring seagrass beds through time can the role of seagrass beds as nursery grounds for fish species be established and investigated.

(2) Expand the survey to encompass a wider range of habitats around Green Island. This will yield added information with which to assess the importance of seagrass beds as nursery areas, and the flow on effects of high recruitment into the adult population. It will also allow the comparison of the recruitment rates and densities of adult fish on Green Island with other reefs on the Great Barrier Reef. Furthermore, this basis of data will allow the effects of *Acanthaster* disturbance to be directly assessed if an outbreak occurs. Other questions such as the effect of highly concentrated effluent outflow on the distribution of fishes can be approached.

(3) Examine the survival, growth rates and fecundity of fishes within and outside the unique seagrass areas. For Green Island and, in particular, its seagrass beds to be important nursery grounds not only must they have a consistently higher density of newly recruited fish, but also these fish must have a similar or better survival rate and adult fecundity. Studies have found that fishes at high initial stocking densities may have either high density dependent mortality, suppressed gonad maturation or reduced average fecundity (e.g. Jones 1984, 1987). If this was found to be the case for fish species within the seagrass environment then it may not be as important an area for stock replenishment as current research would suggest (e.g. Pollard 1984, Bell and Pollard 1988). To approach this question, multiple samples of adult and juvenile fish of a range of species are required for otolith and gonad examination. This is a long-term objective of the study, which requires the assimilation of both the long-term abundance data and detailed information on the biology of fish species.

A budget to fund this valuable research has been prepared with these objectives in mind (see Table 3).

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Table 1. Total abundances of juvenile reef fish counted within and outside the Green Island seagrass bed.

Juvenile Family	Inside Seagrass	Outside Seagrass
Scarids	522	36
Lethrinids	217	0
Mullids	89	0
Siganids	73	23

Table 2. Analyses of variance comparing densities ($200m^{-2}$) of **adult** fish between two sites within and outside the seagrass bed at Green Island. Significance level is given (NS, non-significant). Data is log(x + 1) transformed. * tested with pooled degrees of reedom 1,18.

Source of Variation	Degrees of freedom	Mullids	Lethrinids	*Scarus rivulatus*	*Pomacentrus popei*	*Pomacentrus wardi*	*Chrysiptera rollandi*	*Stethojuilis bandanensis*	*Thallasoma lunare*
Location	1,2*	NS*	NS*	NS*	NS*	NS	NS	NS*	NS*
Site (Location)	2,16	NS	NS	NS	NS	0.05	0.05	NS	NS

Table 3. Budget for proposed research

Personnel: Researcher (Grade 1.4) plus two assistants (Grade 1.4 at $496 / 10day fortnight)	
(a) Re-survey of existing sites for recruit and adult fish densities.	
Two weeks field time	$2083
(b) Expansion of survey into other habitats	
One week field time	$1042
(c) Data storage, analysis and write-up	
Two weeks for single researcher	$ 694
Sub-total	**$3819**
Transport and Accommodation	
Vehicle transport between Townsville and Cairns.	
Two trips at $200/trip	$400
Transport to Green Island.	
Two return trips for 3 people at $15/trip	$ 90
Accommodation at Green Is. resort (reduced rate),	
$55/person/day for 3 people for 21 days	$3465
Boat time, $60/day for 21 days	$1260
Sub-total	**$5215**
Maintenance and Write-up	
Dive gear allowance, $5/person/day for 21 days	$315
Survey materials: tapes, pickets, rope, buoys,	
aerial photographs etc.	$ 400
University on-costs - Administration and report preparation	$ 800
Sub-total	**$1515**
TOTAL	**$ 10549**

Figure Legends

Figure 1. Map of Green Island showing the location of coral bommies sampled for fish and benthic fauna, within 2 sites at a Seagrass and Non-seagrass area.

Figure 2. Mean density of **juvenile** reef fish within ('Seagrass') and outside ('None') the seagrass bed (n = 5). Categories represent sampling sites: 1, site 1; 2, site 2; E, on bommie edge; O, in open seagrass or over sand.

Figure 3. Mean density of **adult** reef fish within ('Seagrass') or outside ('None') the seagrass bed (n = 5). Categories as for Fig. 2.

Figure 4. Mean percentage abundance of benthic substratum categories measured by line-intercept transects (n = 3).

Figure 5. Mean density of **adult** reef fish on six bommies within two sites at Arlington Reef.

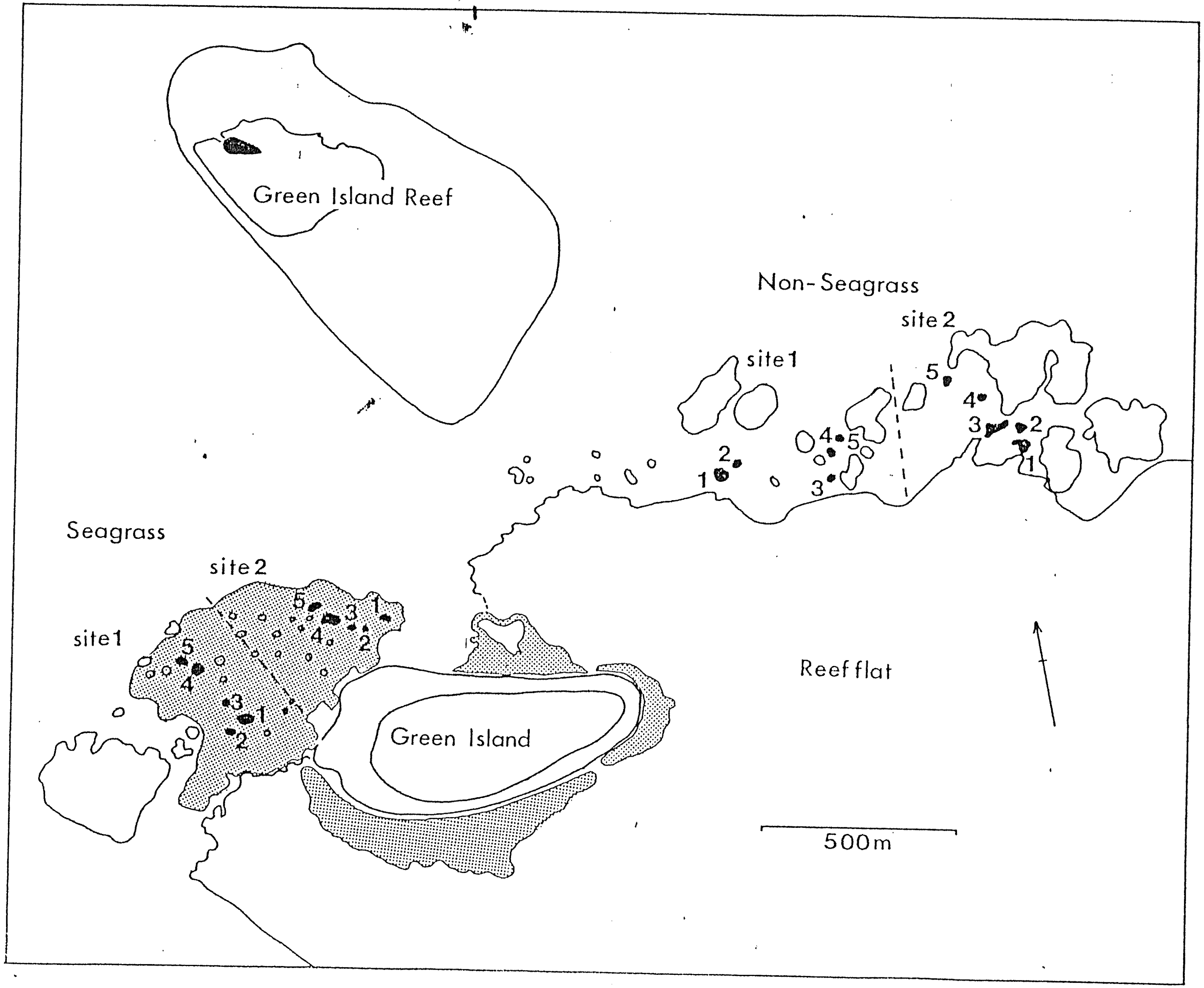

Green Island Reef
Non-Seagrass
site 2
site 1
5
4
3
2
1
2
1
4
5
3
Seagrass
site 2
site 1
5
3
1
4
2
5
4
3
1
2
Green Island
Reef flat
500m

Fig. 1

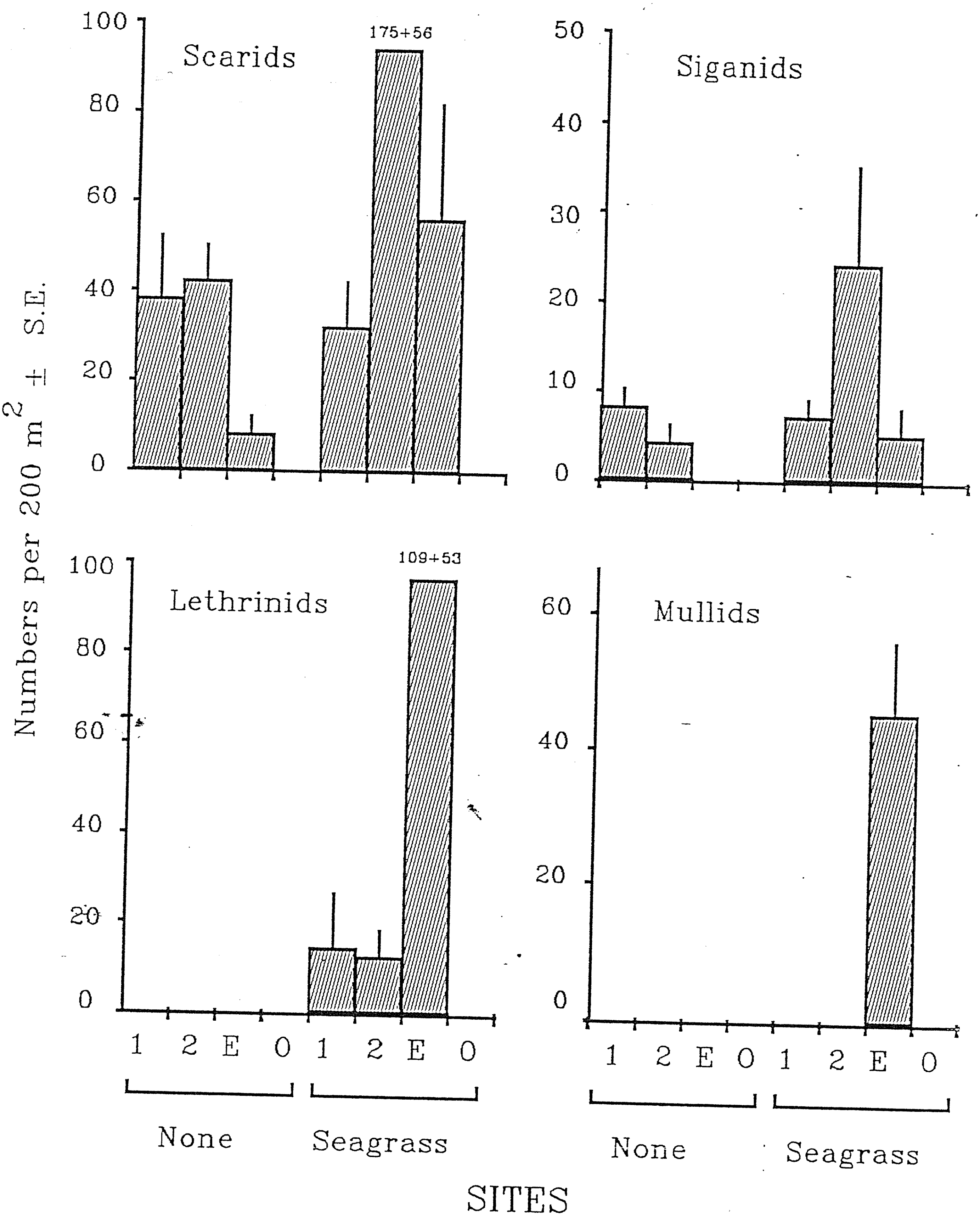

Scarids
175+56
Siganids
Lethrinids
109+53
Mullids
Numbers per 200 m² ± S.E.
100
80
60
40
20
0
50
40
30
20
10
0
60
40
20
0
1 2 E 0 1 2 E 0
None
Seagrass
SITES

Fig. 2

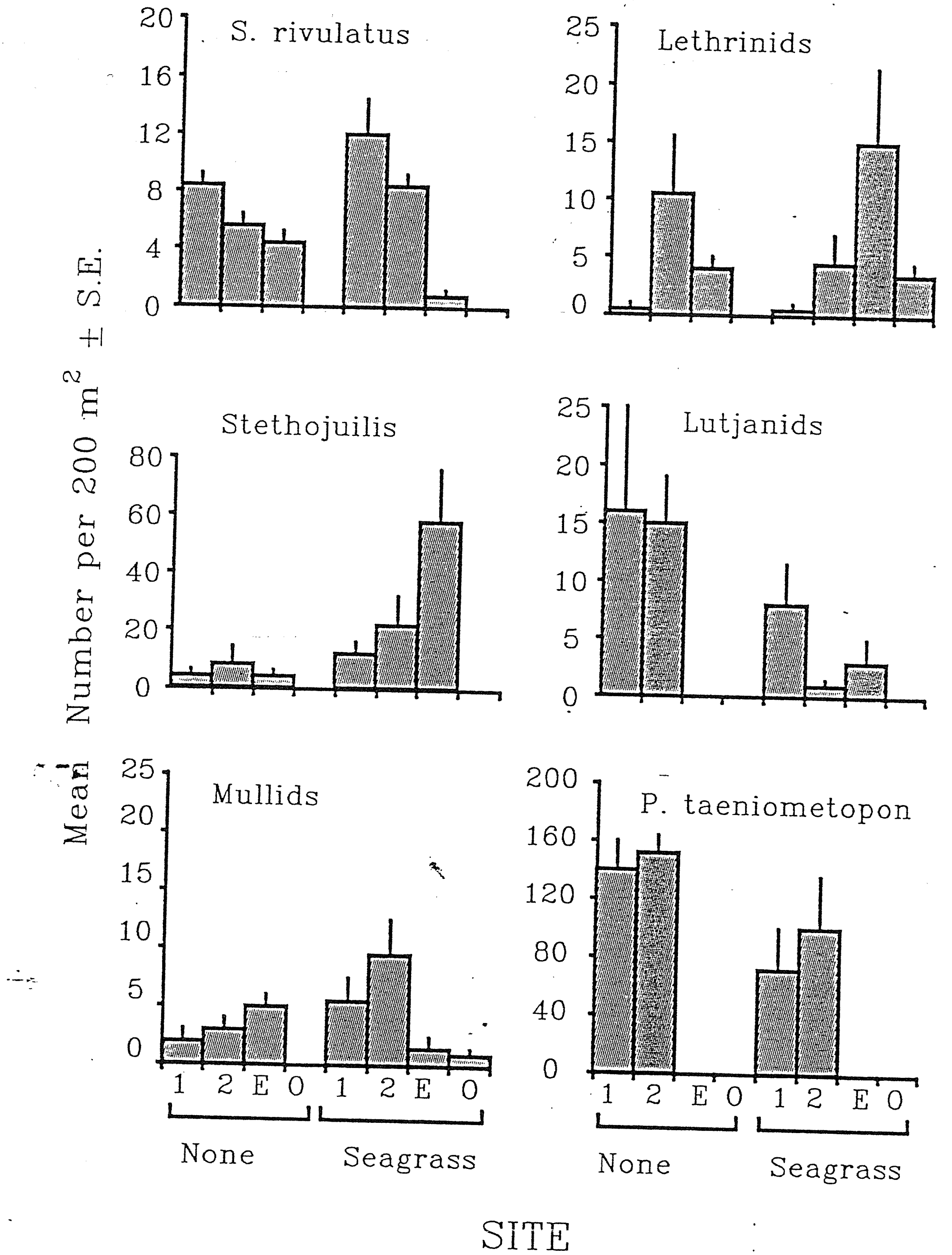
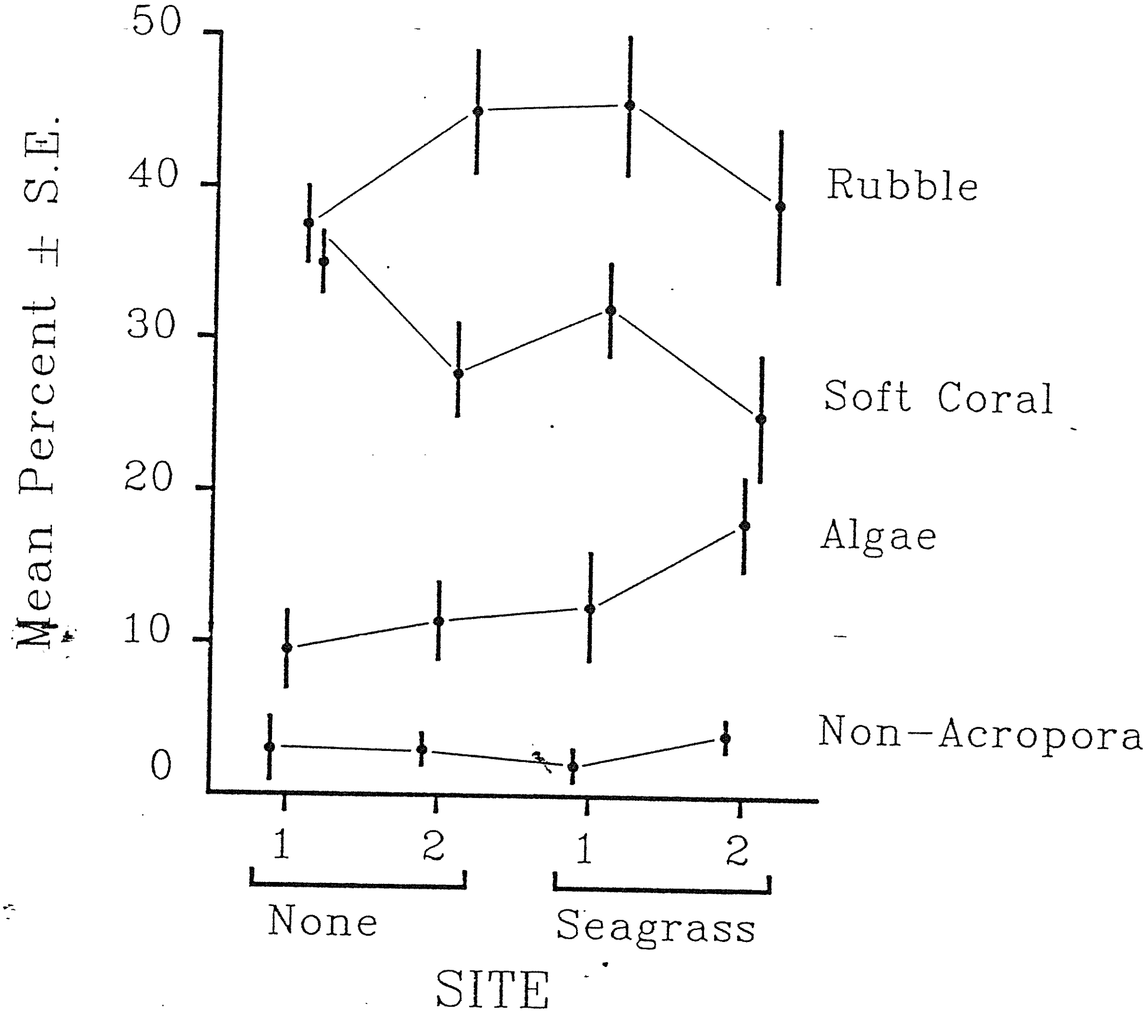
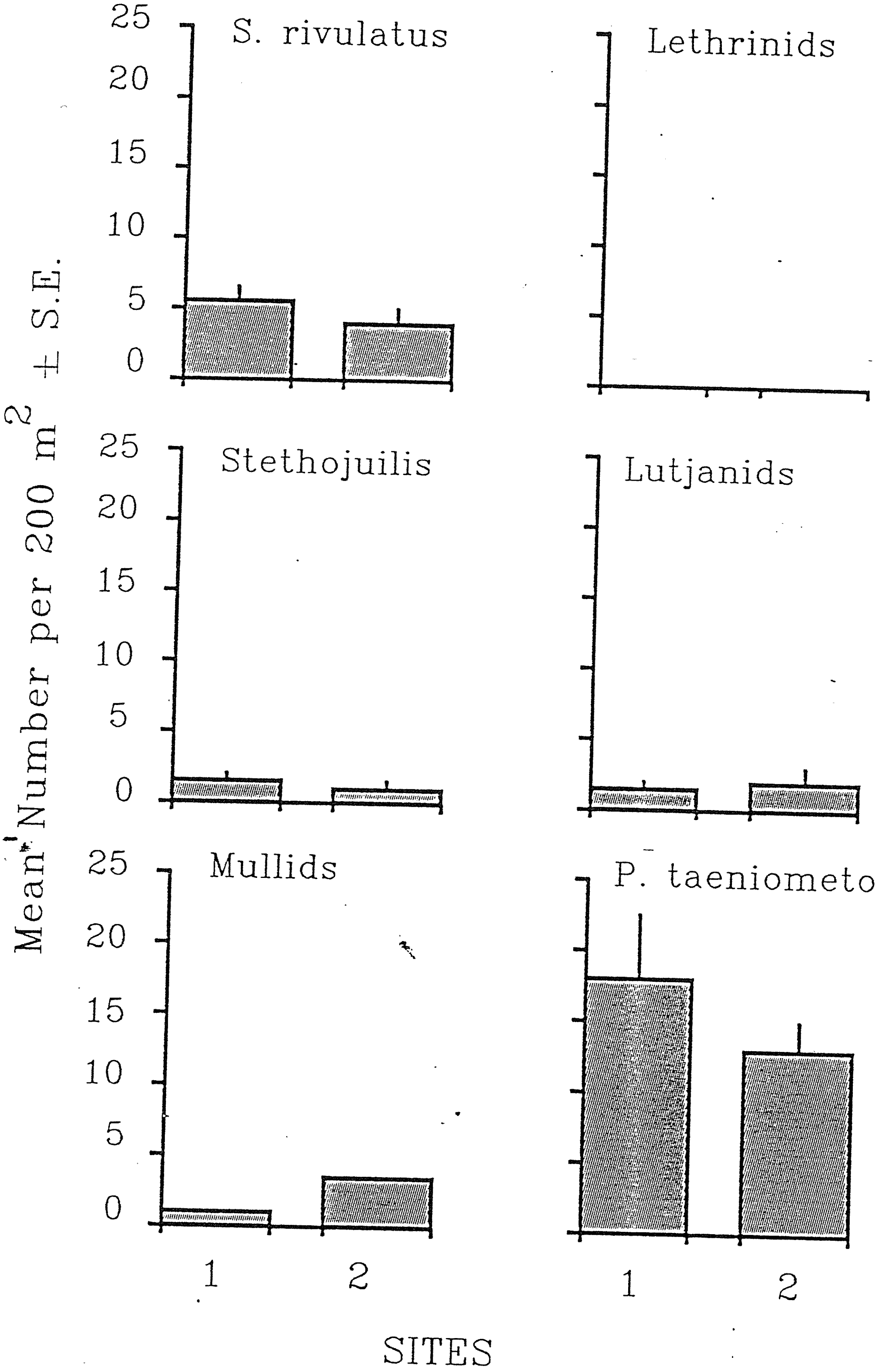

S. rivulatus
Lethrinids
Stethojuilis
Lutjanids
Mullids
P. taeniometopon
Mean Number per 200 m2 ± S.E.
1 2 E 0 1 2 E 0
None
Seagrass
SITE

Fig.3



Mean Percent ± S.E.
50
40
30
20
10
0
Rubble
Soft Coral
Algae
Non-Acropora
1
2
1
2
None
Seagrass
SITE

Fig. 4



S. rivulatus
Lethrinids
Stethojuilis
Lutjanids
Mullids
P. taeniometopon
25
20
15
10
5
0
Mean Number per 200 m2 ± S.E.
1
2
SITES

Fig.5