INTERNAL REPORT NO. 2

A Preliminary Report on a Pilot Investigation to Maximise Tasmania's Sea Urchin (Heliocidaris erythrogramma) Resource

J Craig Sanderson
Principal Investigator

September 1993

SEA FISHERIES DIVISION
MARINE RESEARCH LABORATORIES - TAROONA
DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES, TASMANIA

Department of Primary Industry and Fisheries,
Sea Fisheries Division

INTERNAL REPORT NO. 2

A Preliminary Report on a Pilot Project to Maximize Tasmania's Sea Urchin (*Heliocidaris erythrogramma*) Resource.

J Craig Sanderson
October 1993

A FRDC funded project in conjunction with
Tasmanian Sea Urchin Developments.

Requests for copies of this report or queries can be made to Craig Sanderson:
c/- Tasmanian Sea Urchin Developments, P.O. Box 172 Moonah, Tasmania 7009,
Fax/Ph. No.: (002) 233510 or to
Tasmanian Sea Fisheries Division, Taroona Research Laboratories
Crayfish point, Taroona 7053
Ph. No.: (002) 277277.

ABSTRACT

A commercial fishery for *Heliocidaris erythrogramma* has been in progress in Tasmania since 1983. At present (1993) there are two processors and 30 commercial divers of which 15 work at least 8 months of the year. For 1992, divers estimated total annual landings at about 520 tonnes with a value of approximately $2m. This study is aimed at maximizing the value of these resourse through controlled fishing. This report details preliminary findings.

A quadrat size of 5 x 1m is determined as the optimal size for density determinations at the two research sites, Hope Is in the south of Tasmania and at Meredith Point in the east. Measured densities of urchins at these two sites are 2.8 $\pm$11% and 4.1 $\pm$15% per m^2 respectively (25 x 1m quadrats used). Urchin sizes are greatest in vegetated areas with smaller urchins in shallower waters in those areas. Roe recovery as a proportion of urchin weight is least in barren areas. Roe condition (colour and coarseness) deteriorates with increasing size (age) of the urchin. The size at which deterioration occurs is site dependant. Roe of urchins from barren areas is in poorer condition at smaller sizes.

INTRODUCTION

History of Tasmanian Sea Urchin Industry

Trial fishing for *Heliocidaris erythrogramma* began in Tasmania in the 1960's, but most the fish landed were poor quality and there were no established markets. The first quality roe was landed in 1983 for a newly developed market in Melbourne. In 1985 three divers began export sales to Japan sparking a speculative demand for licenses. In that year 250 commercial licenses were issued.

Currently there are about 30 commercial divers working on sea urchins between St Helens on the east coast and Dover in the south. Some are part timers, but about 15 work systematically for not less than eight months a year, each aiming to land an average of 1 tonne (live weight) a week. The divers use hookah gear and work mainly in pairs, although a few work solo or with a deckhand. The total catch is taken inside the seaward limits of bull kelp. About 95% of fish are retrieved from water averaging 4 meters in depth but in a few specific areas divers work as deep as 25 meters.

Until December 1992, virtually all sea urchins were sold live to two specialist processors and exporters: Oceania Trading Pty Ltd in southern Tasmania and Tashimi Fish in northern Tasmania. Oceania grades and ships the roe on traditional wooden display racks for auction in Japan, employing three to four processing workers for each supplying diver. Tashimi fish sells its roe in bulk for re-packaging overseas employing two to three processing workers for each supplying diver.

Divers are paid for roe weight recovered. In late 1992 Tashimi Fish paid $26-/kg; Oceania $30-/kg. Prices in Japan for Tasmanian roe fluctuate considerably because of the inconsistency of the product. In 1992 prices typically ranged between $A80- to $A120-/kg and peaking at $250-/kg.

Divers estimate total annual landings (to December 1992) at about 520 tonnes gross. Annual Tasmanian roe exports are estimated by divers to be about 18.2 tonnes. The 1992 FOB value of the fishery is estimated by divers to have been about $A2m.

Justification for present research aims

At present the current fishery is unmanaged. Consequently the average roe quality is poor and the harvest season is short, which results in minimal returns and prevents the fishery realising its immense potential.

In many Tasmanian coastal areas, 'urchin barrens' are evidenced with reduced availability of foods preferred by urchins, including the important native string kelp, *Macrocystis pyrifera*. Denied sufficient food, vast colonies of sea urchins are unprofitable because of their minimal roe weights while, at the same time, our observations indicate they are devastating algal growth in the coastal zone to the detriment of other marine species and the coastal ecosystem.

There is an urgent need therefore to develop cost effective, commercial enhancement techniques for these key areas which will restore biological balance and maximise the fisheries value and employment potential by increasing both roe weight and roe quality.

With the aim of optimising this resource, funding has been allocated to Tasmanian Sea Urchin Developments through the Commonwealth funding agency FRDC (July 1993, Pr. No. 93/221) to initiate a pilot program to maximise Tasmania's sea urchin Resource.

Research Sites

The principal thrust of the project as detailed in the application entails manipulating densities of urchins and monitoring resulting roe yield and quality. To this end two lease sites have been allocated to Tasmanian Sea Urchin Developments for the project by the Division of Primary industry and Fisheries, one at Hope Island in the south and the second at Meredith Point on the east coast (see fig.1a-c) . These areas are restricted to other urchin divers allowing control over experimental conditions.

Hope Island.

Hope Island is an island 2-3 km from the jetty at Dover in Port Esperence (Fig. 1b). Rock type is predominantly dolerite. It receives slight swell action on its south east corner during a large southerly roll (infrequent). Maximum depth for most of the island is less than 12m within 100m of the island. A shallow sand bottom broken by occasional low reef, at less than 6m depth extends from the north western side towards Faith and Charity Islands.

Macroalgal vegetation is confined to a fringing rim to less than 2m depth for most of the island except for the south eastern and the south western corner where the vegetation can extend to the limit of firm substrate. The dominant algae on the wave exposed side consists of *Phyllospora comosa*, *Cystophora moniliformis*, *Acrocarpia panniculata* and *Carpoglossum confluens*. On the more sheltered side, dominant algae are *Phyllospora comosa*, *Macrocystis pyrifera*, *Ecklonia radiata*, *Cystophora retroflexa* and *Sargassum fallax*.

Below the fringing algal rim, the rocks are mostly bare except for some encrusting coralline algae. Most of these 'bare' rock surfaces are free of silt or turfing algae possibly due to the action of tidal currents in the area (tidal range of approx. 1 meter) and/or the action of herbivores continually scraping the rock surfaces. These areas are termed 'urchin barrens'.

Caulerpa species can be found on the sand adjacent to the reef and the seagrass *Heterozostera tasmanica* is found further out on the sand. Also on the sand on the north western side shells and shell fragments are common. Occasional urchins can be found on the sand in this area using the fragments for camouflage.

Anecdotally, Hope Island is poor for sea urchin roe recovery with only the infrequent bin harvested. This reflects the situation for much of the D'Entrecasteaux Channel.

Meredith Point

In contrast to Hope Island, Meredith Point (Fig. 1c) is an area of good recovery in terms of urchin roe yield. According to local divers in 1992, 10-20 tonnes of urchin were harvested from this approximately 2.0 km of shoreline. The substrate here is predominantly dolerite with sandstone towards the western edge of the lease area. Depths are maximum on the eastern side where they can reach 8-12 m within 100 m of the shore. From the south eastern corner of the shoreline, a reef extends south outside the lease area to approximately 1km (?) off-shore, averaging 4-5m depth to the top of the reef. For the remainder of the site, the reef meets the sand at 4-5 m depth.

On the eastern section of the lease area, there is a band of macroalgal vegetation in the shallow water with barrens below. This band consists mainly of *Colpomenia* sp., *Zonaria* sp., *Cystophora* spp. and *Caulocytsis cephalinorthis*. Below this the rocks are bare until the reef - sand edge where *Caulerpa flexilis* is dominant. Over the 'bare rocks' a fine turfing alga is common along with much silt. The introduced alga*Undaria pinnatifida* is a rapid colonizer of these bare areas in the spring. Growth is fastest in the shallows for *Undaria* with a climax in late summer.

From the south eastern corner to the western edge of the lease, macroalgal cover extends from the low tide level to the extent of hard substrate. *Cystophora* spp., *Sargassum* sp., *Acrocarpia panniculata, Caulocystis cephalinorthos* and *Zonaria* sp. are common in the shallows. *Sargassum fallax* (?), *Caulerpa flexilis* and other *Caulerpa* spp. become more common in the deeper waters (>2m). *Heterozostera tasmanica* is on the sand beyond the reef edge.

Tasmania's predominant swell direction is from the west. Easterly swells are infrequent and are more likely to occur over the summer period. Meredith Point is protected from direct easterly swells by Maria Island but occasional swell action can be quite significant.

The following report details preliminary investigations in these two lease areas. The investigations can be divided into three parts:

1. Determination of appropriate quadrat size for sampling urchins (QUADRAT SIZE).

2. Size frequency of test diameters and roe analysis at the two lease sites (SIZE FREQUENCY AND ROE ANALYSIS) and

3. Mapping of vegetation, substrate and urchin numbers at the two sites (MAPPING OF LEASE SITES).

Urchin divers associated with Tasmanian Sea Urchin Developments used in this program to be acknowledged are Will James (WILL), Maurice Le Rossignol (TINY) and Mathew (MAT).

1. QUADRAT SIZE

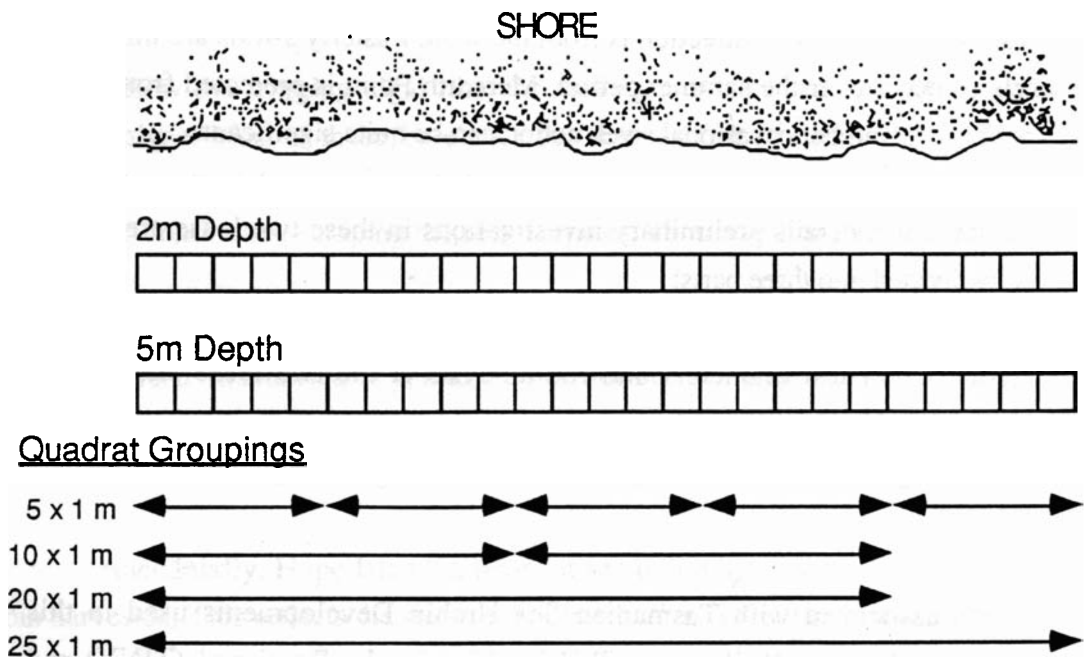
To ensure optimal sampling strategy in determining density of urchins at the various sites, quadrats of varying sizes were tested.

METHOD

To determine appropriate quadrat size, five sites were sampled at the two lease areas (see fig.1b). At each of these five sites, at sections of the coast chosen arbitrarily, a meter square quadrat was laid down successively 25 times parallel to the shore at both 2m and 5m depth (see fig. 2). Urchins were counted in each quadrat with the number below 40mm (estimated) noted. By combining quadrats in various combinations, the precision of using varying quadrat sizes for calculating urchin density could be determined (see Andrew and Mapstone 1985).

The haphazard selection of quadrat/transect locations gives an indication of urchin densities and variation at both the sites.

Figure 2 Diagram showing quadrat arrangement in relation to the shore and subsequent groupings for varying quadrat size.



The factor of depth has been included as Dix (1970) noted changes with depth in his reports on *H. erythrogamma* in Tasmania. Also divers claim better return in shallow waters compared to deep and personnel observation indicates that barren areas in sheltered waters tend to be in deeper water (>2m).

Two divers were used to conduct density determinations at Hope and one at Meredith. The principal investigator did the deep quadrats at both sites and the shallow at Meredith, while 'TINY' did the shallow at Hope Island.

Auto correlation between successive quadrats would also be tested to determine the necessity for random allocation of quadrats.

RESULTS

1. Quadrat size

As might be expected, the quadrat size for greatest precision for equivalent number of quadrats is the largest: 25 x 1m (fig. 3), although there is little difference between these, 5 x1m , 10 x 1m and 20 x 1m sizes. As searching time is linearly related to the area searched, 5 x 1m quadrats would appear to give the best result for least time involvement.

The mean standard error as a percentage of the mean (also a measure of precison) for various clumpings of 5 x 1m quadrats indicates a minimal area of 15 quadrats to be sampled for acceptable precision of less than 15% (fig. 4).

The 1 x 1m quadrats are used for density estimates in Figure 5a. This is not statistically correct however due to the sampling strategy (quadrats not randomly allocated) and some auto-correlation was detected (fig.5b). They do indicate however a trend of higher density of urchins in the deeper waters which is confirmed when the 25 x 1m quadrats are used to compare density differences for the two depths at both the sites (Table 3).

The low mean values for urchin numbers for 1 x 1m quadrats (<5) also indicate that a size of at least 5 x 1m quadrat would be more appropriate for sampling (urchin numbers >15).

Auto-correlation was checked by plotting quadrat density readings against subsequent readings (fig.5b). These indicate a high correlation for shallow quadrats and not significant for deep at both sites for 1x1 m quadrats.

DISCUSSION

Quadrats of 5 x 1m appear to be the optimal size for best precision and minimal time commitment. They also result in a reasonable number of urchins per quadrat for easy comparison. The higher variation in density readings for the 1 x 1m quadrats is probably a reflection of patch size in the distribution of these animals.

2. SIZE FREQUENCY AND ROE ANALYSIS.

Measurements on variation in gonad condition and size were required on which to base later sampling strategies.

METHOD

At four arbitrarily chosen sites within both lease areas 100 urchins were harvested at 2m (shallow-'S') and 5m depth (deep 'D') for measurement of diameter and weight (NB: different sites to Section 1., see fig.s 1b & c). This was done on 4.7.93 at Hope Island and 22.7.93 at Meredith Point. All urchins seen were collected eliminating bias towards any particular size. Boulders were not overturned but crevices and nooks examined. At two of the sites within each lease, 25 urchins were sub-sampled from each 100. Roes were dissected out and weighed in the laboratory (DPIF, Taroona) and condition and sex noted (results also include urchins collected at second gonad sample Aug. 1993). Percentage recovery was determined as:

(wet weight of roe / the wet weight of the total urchin) x 100

The condition of roes has importance commercially. Colour and coarseness is considered. For colour, a coding from white (1), yellow (2), orange (3), brown (4) and black (5) was used. For coarseness, roes were divided into very fine (VF), fine (F), coarse (C) and very coarse (VC). Male urchins tend to have finer roe.

'A' grade roe, suitable for the Japanese market, is white-yellow and fine-very fine. 'B' grade roe includes these and orange and coarse grades. In 1992 'A' and 'B' grade roe was processed by the northern Tasmanian processor. In 1993 no market has been found for 'B" grade roe.

RESULTS

Hope Is.

Modal test diameter at Hope Is is 65-70mm. Mean test diameter is greatest at the more vegetated sites. Generally there was little difference between sites and between shallow and deep at each site (figs 6-7, table 1) except at the more exposed (2S & D) and/or vegetated locations (5S* -not presented; mean diameter: 79.0mm ±0.8 s.e., sampled Aug. 1993).

Percentage recovery of roe (figs 8a & b) is least at site 1-deep (1D). This coincides with an area barren of larger thallose algae.

TABLE 1. Mean size of urchins (mm, +/-s.e.) collected at both lease areas from all sites.

	HOPE ISLAND	MEREDITH POINT
SHALLOW	70.1 ±0.5 (n=410)	76.21 ±0.5 (n=425)
DEEP	69.2 ±0.6 (n=446)	77.5 ±0.5 (n=425)
OVERALL	69.7 ±0.4 (n=856)	76.8 ±0.3 (n=850)

Meredith Point

Modal test diameter at Meredith Point is 80-85mm. There is a tendency for urchins with larger tests to be in the deeper water (fig. 10-11, note that 2S and 2D are not directly comparable as they correspond to different areas of the coast).

Percentage recovery of roe (fig 12) is least at site 1-deep (1D). This coincides with an area barren of larger thallose algae. The sampling size of 25 appears to be sufficient to discriminate percentage roe recovery of urchins from barren and vegetated areas.

Gonad Condition

A line of best fit using a quadratic equation of all urchins harvested so far is presented for both sites in Fig. 13. This includes all urchin (a) and only those urchins from outside the barrens (b). Note the higher recovery for urchins outside the 'barrens'. All fitted curves are significant at at least the .05 level despite the apparent wide spread of points. A quadratic equation was used as this was the anticipated relationship between % recovery and diameter based on anecdotal evidence. The result presented here is not necessarily proof of the relationship however.

* Code relates to transect number (see section 3.) and 'S' to shallow. Warning! note that as the numbering system for sections 1, 2 and 3 are similar and shallow 'S' and deep 'D' are the same beware of confusion in interpreting results).

Judging coarseness of the roe tends to be very subjective and discrimination is not always consistent. Results show a statistically significant difference for the diameter of urchins with differing colour roe however. Undesirable roes (very coarse and brown-black colouration) tend to occur in the larger urchins (>80mm) and optimal recovery is obtained from mid sized animals (65-85 mm diam., fig. 14 & 15) but this can be site specific (fig. 16-18) ie. barren areas with smaller urchins have coarser, discoloured roes at a smaller size.

Percentage recovery of roe from monthly samples for the first four months (July-Oct.) for both sites is depicted in Figure 19. They demonstrate consistant significant differences in roe recovery of urchins from 'barren' areas compared to vegetated areas for both the sites and a gradual overall increase since the start of monitoring.

DISCUSSION

Overall mean diameter of urchins is similar for shallow and deep waters but there is a tendency for a greater test diameter in deeper waters on the more exposed vegetated sites. This may be due to some grading as a result of the swell action and limited mobility due to the algal cover. Greater vegetated sites in general tend have larger test diameters.

Percentage recovery of roe is least within the barren areas but can be good at the barren-weed fringe (<2m depth). This agrees with diver experience.

Although percentage recovery from the urchins in this trial appears good relative to optimal diver recoveries (approx. 4-6 %), if undesirable roes here are eliminated, then overall percentage recovery is greatly reduced (Table 2). Introducing grading of urchins using a cutoff based on the results of increasing coarseness and decreasing colour with age/size (fig.s 14 and 15) increases percentage recovery. This indicates a greater return for divers who are selective in their sizes when harvesting (Meredith Point only). These results may be improved again if confined to 'good' (vegetated) areas only as the results here include barren areas.

TABLE 2. Overall percentage recovery for **1)** ' A' and 'B' grade roe and **2)** 'A' grade only.

HOPE IS.	Total Urchin Wt. (gm)	Roe Wt. (gm)	% rcvry	MEREDITH POINT	Total Urchin WT. (gm)	Roe Wt. (gm)	% rcvry
TOTAL	26670	1) 964.7	3.6	TOTAL	23997	1) 1428.8	6.0
		2) 312	1.2			2) 555.7	2.3
<75mm diam.	9807	1) 342.8	3.5	<78mm diam.	11224	1) 817.2	7.3
		2) 103.7	1.1			2) 321.7	2.9

3. MAPPING OF LEASE SITES.

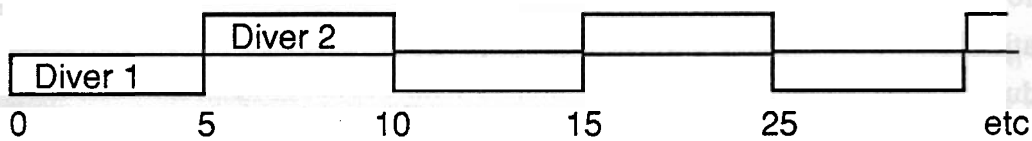
Knowledge of the vegetation, substrate and urchin density distributions at the two sites were required before the pilot study is to proceed.

METHOD

Both sites were divided into equidistant sections. These have been marked with numbered boards at both sites to enable re-location. Transects were run perpendicular to the shore at each of these marks (see fig.1b & c). The transect line consisted of a 100m length of 7mm rope marked every meter with lead 'net' weights and canvas 'flags' every 5 meters with the distance inscribed. Using a meter length of PVC pipe, urchins were counted for five meter lengths of the transect line within a distance of a meter from the line. Two divers were used for each transect.

The divers did alternate 5 meter sections contiguously (see fig.20). Diver 1 (principal investigator) used a 0.25m^2 quadrat, laid at each 10m mark (always starting from '0') to record vegetation cover. The quadrat was divided by seven lines running horizontally and vertically giving 49 intersection points. These and one of the corners gave 50. Substrate was divided into Reef, Boulders (0.5-1.0m diam.), Rocks (0.1-0.5m diam.), Rubble (0.02-0.1m diam.), Sand and Shells. Algae were divided into species as best as possible underwater. Algal cover and substrate were given a reading based on the number of points intersected. Total cover for algae can come to a number greater than 50 due to successive layers of algae.

Figure 20 Diagram showing contiguous arrangement of quadrats about the transect line (numbers are distance along the transect line in meters).



Recordings were made only for the extent of hard substrate as urchins are not generally not found on sand.

RESULTS

Figures 21 - 28 are a graphical representation of results. Algae have been identified to species level in the field but clumped to give representation as indicated. Full details of all species are available on request.

Barren areas are distinguished by few fleshy algae (excluding filamentous varieties and thus probably ephemeral) and high coralline readings (at Hope Island) or high fine turf readings (at Meredith Point).

Figure 29 shows the difference between counts for the divers for alternate contiguous quadrats. The chief investigator (JCS) did all transects. Other divers (WILL, TINY and MAT) counted contiguous quadrats. Overall there appears to be little difference between divers.

Figures 30 & 31 show the relationship between various parameters and urchin numbers. To reduce the effect of the availability of substrate on urchin numbers, quadrat readings with substrate counts of less than 25 (50%) have been eliminated where indicated. A number of parameters (Total Algal Cover, Fine Turf, Encrusting Corallines etc.) were plotted against urchin numbers but presented here only where possible relationships are evident.

Hope Island

Urchin numbers show a reduction with depth. There are also negative correlations with cover of encrusting coralline algae and Laminariales.

Meredith Point

Again a reduction in numbers of urchins is noted with depth. This occurs also with total cover of brown algae but not total Laminariales cover as for Hope Island.

Auto-correlation

A correlation between successive quadrats (fig 32) along the transect line at both sites is noted. This is due to the apparent reduction in numbers with depth. Stratification of the sampling regime by depth is indicated so to more properly separate causative factors on urchin density.

Estimates of urchin densities do not differ significantly from estimates made in section 1 (see Table 3) especially if auto-correlation is considered and the consequent actual increase in uncertainty of error.

TABLE 3. Comparison of urchin density estimates made from section 1 and section 3 standardized to 1 x 1m (±s.e.)

	Orig. Density Est.s (25 x 1m quad.s)			Final Density Est.s (5 x 1m quad.s)
	SHALLOW	**DEEP**	**OVERALL**	**OVERALL**
Hope Island	2.2 ±10%	3.5 ±9%	2.8 ±11%	2.4 ±8%
Meredith Point	5.7 ±12%	2.5 ±8%	4.1 ±15%	3.2 ±9%

DISCUSSION

Findings so far are consistent with research in California and Canada. Evidence supports urchin mediated barren areas in coastal areas around Tasmania. Densities are highest at the edges of these barrens with a lower density of urchins required to maintain the barren condition. Urchin distribution is determined by wave action and can act preferentially against larger urchins. Most barren areas do not extend beyond less than 2 meters depth due to wave action.

Urchins with the highest percentage recovery of roe by weight are generally found in more highly vegetated areas or at the edges of the barrens.

Larger urchins tend to have undesirable roe. Cutoff sizes for optimal roe condition are site specific however, being lower within barren areas. This suggests that roe condition may be age related and urchin in slower growing areas such as are believed to occur in barren areas have poor roe at smaller sizes.

Monthly samples of roe condition at both sites indicates an increase from winter to early summer, with urchins from barren areas consistantly having significantly less percentage roe recovery than those from vgetated areas.

Anecdotal evidence suggests good roe recovery also occurs in deeper water (10-30 m) tidal areas such as in the middle of the Mercury Passage and at the top of the D'Entrecasteaux Channel. Urchins presumably feed on drift algae in these areas. At present, these areas will not be considered as part of this program.

Proposed program July1993 - July1996 FRDC Grant

The initial program as detailed to FRDC entailed principally manipulating densities at the two sites and monitoring recovery with the anticipated result of improving gonad condition. The means of determining density will be achieved by different harvesting regimes. To this end both lease sites will be sub-divided into nine sections.

At each of the sites three of the sections will remain un-fished until the final year of the program in the summer of 1995 (control areas). Three of the sections will be fished in 1993 and 1995 and three will be fished in all three years 1993,1994 and 1995.

Fishing intensity will be severe, with a revisit after at least a month to re-harvest for any missed fish. Catches from each of the sections will be carefully monitored. All sections will be fished in the spring-summer period. Urchins only greater than approx. 60mm will be harvested as results from above indicate that urchins below this size have minimal roe recoveries (probably immature) at both lease areas.

At Meredith Point, the sections will be large enough (80-100m along the shore) that movement of urchins between areas will be minimal. Buffer zones will be utilized. At Hope Island, where wave action is minimal it is likely that fences will be used. These are presently being trialled. Sections will be a lot smaller here at 20-30m of shoreline.

The two different methods employed to subdivide the coast are done so for practical (fences are easier to implement at Hope Island) and economic considerations (Meredith Point can presently be fished profitably while Hope cannot). The use of smaller areas at Hope Is. ensures minimal time involvement at this site.

Monitoring the sites will be done on a quarterly basis. Monitoring will consist of transects, size frequency analysis and gonad condition.

Transects

Transects will be conducted for urchin density determinations and vegetation analysis. The actual methods used at each site are determined by the results of this preceding report. There will be two for each section, both cross shore, one at 2m depth and one at 5m depth using 1 x 5m quadrats.

Size frequency analysis

This will be done to monitor the new age class moving through the population and in conjunction with the gonad analysis and density determinations give an indication of total gonad harvestable. It will probably consist of 100 animals from 2m and 5m depth.

Gonad condition

At each quarter 25 urchins will be harvested at 2m and 5m depth within each of the sections. These will be analysed for roe condition and percentage recovery.

Other aspects to the program are the surveys, monthly gonad analysis at both sites and some growth and movement studies.

Surveys

Transects to determine the relationship between vegetation cover and urchin density are being conducted at a number areas to determine a possible 'critical' density for the formation of urchin barrens. Data will also indicate how representative the lease areas are of conditions generally and the possible application of management procedures trialled generally. This may include a visit to the north coast and may result in the spin-off of opening further areas for fishing.

Monthly Gonad Analysis

Twenty five urchins are harvested from a barren area and a 'good' vegetated area every month at both the sites outside of intended treatment areas. This gives a record of variation with time of gonad condition and may lead to an insight into the environmental cues for improved gonad condition and spawning periods. Temperature loggers are being installed at both sites.

Growth and Movement Studies

Some urchins will be tagged at both sites and movement and size measured regularly, probably in conjunction with the regular sampling for gonad condition.

The urchin divers associated with the program also intend small scale pilot projects. These consist of transplanting small unproductive urchins to to higher productive areas within the sites and monitoring recovery and trying to re-initiate the growth of *Macrocystis pyrifera*. These aspects however have low priority.

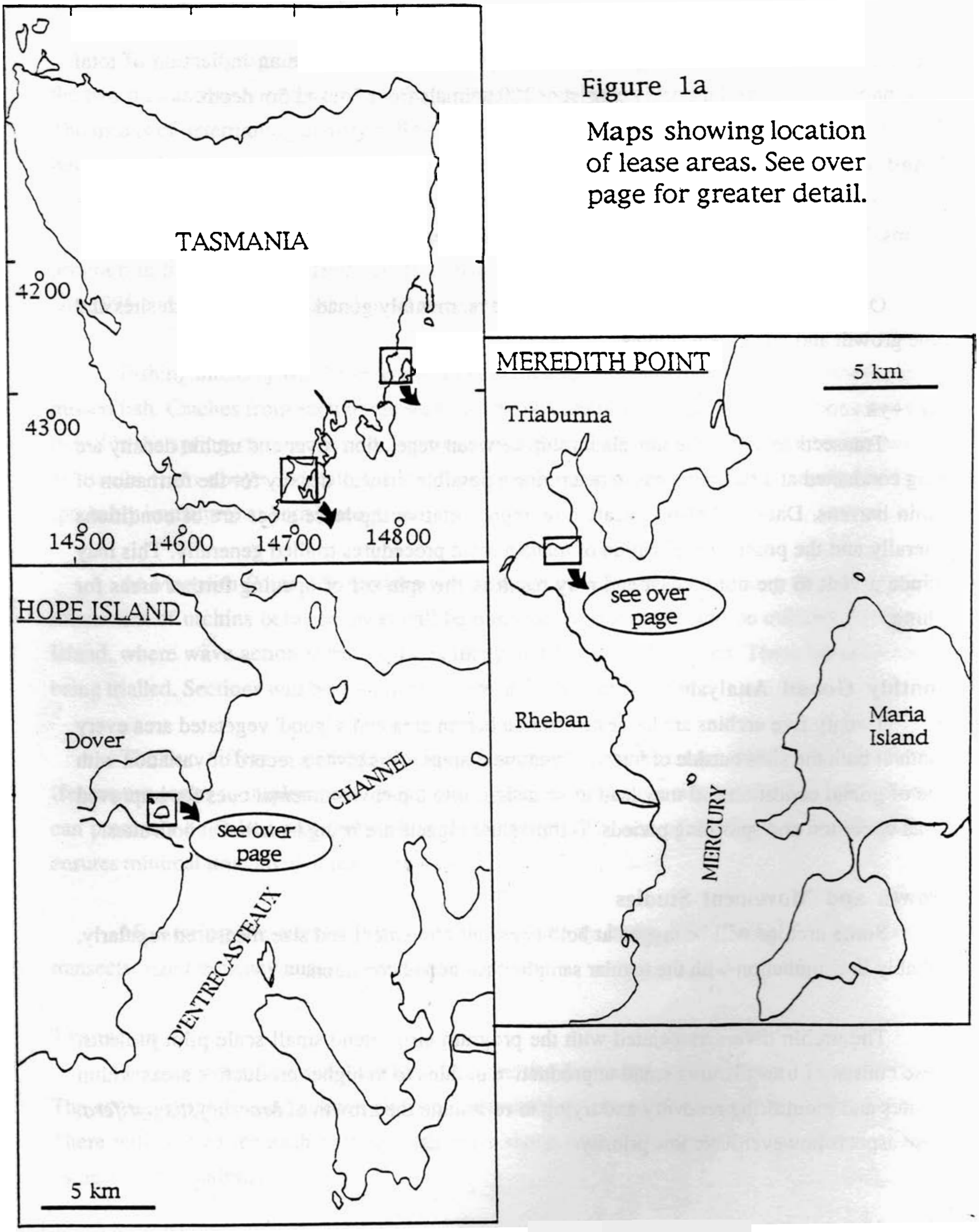
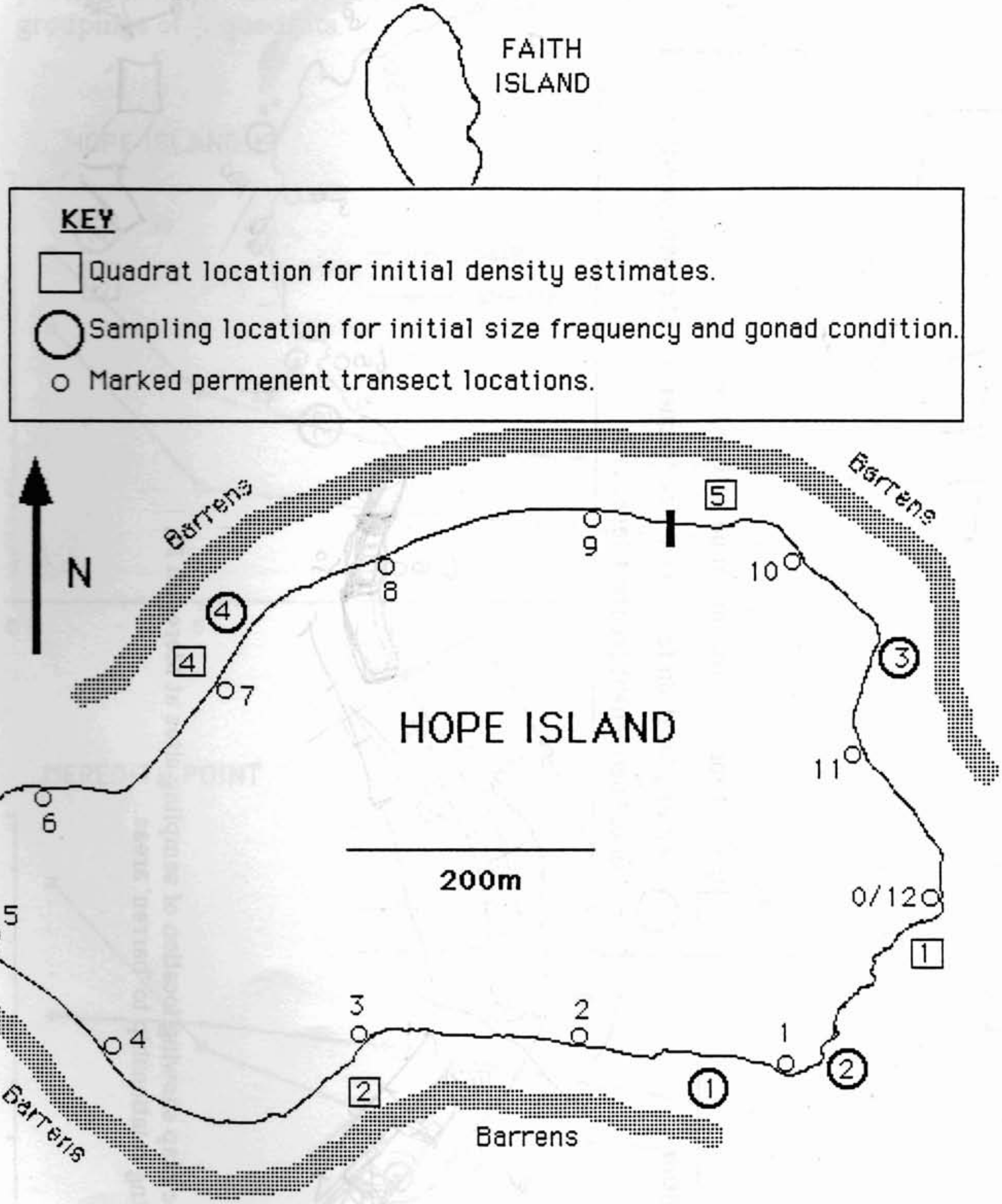


Figure 1a

Maps showing location of lease areas. See over page for greater detail.

Fig. 1b Map showing location of sampling sites at Hope Is, including relationship to 'barren' areas.



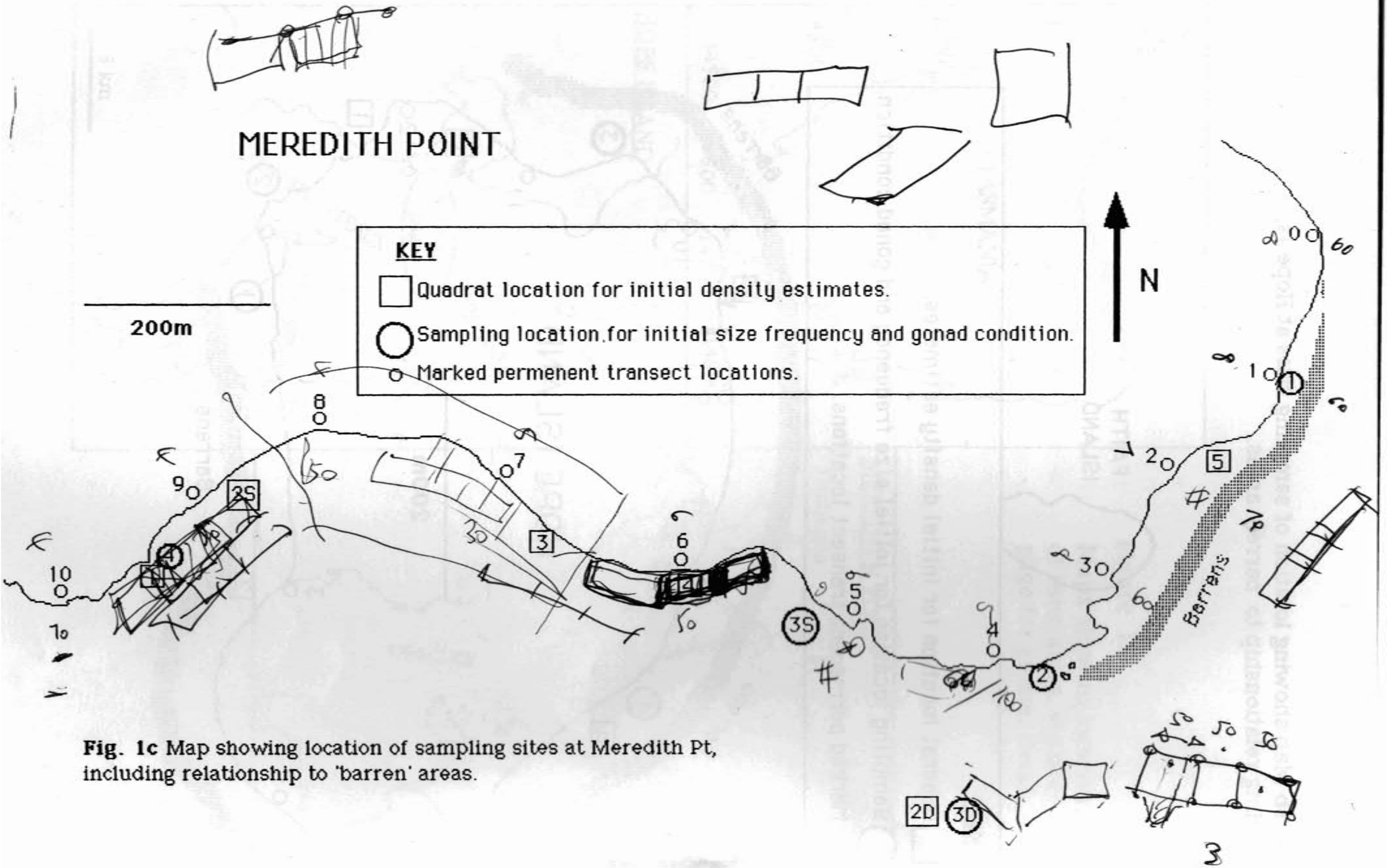
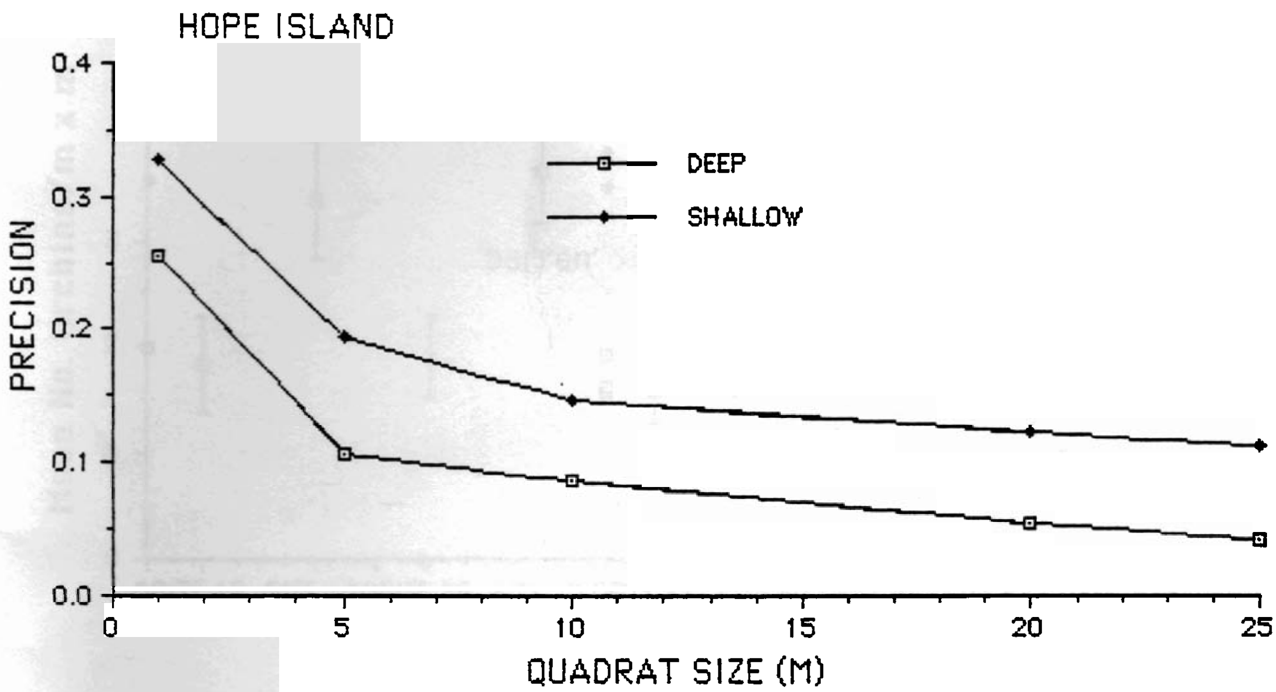


Fig. 1c Map showing location of sampling sites at Meredith Pt, including relationship to 'barren' areas.

Figure 3
Graphs of precision levels for varying quadrat sizes where precision: $SE/\bar{X}$. Results are mean precision calculations for groupings of 5 quadrats.



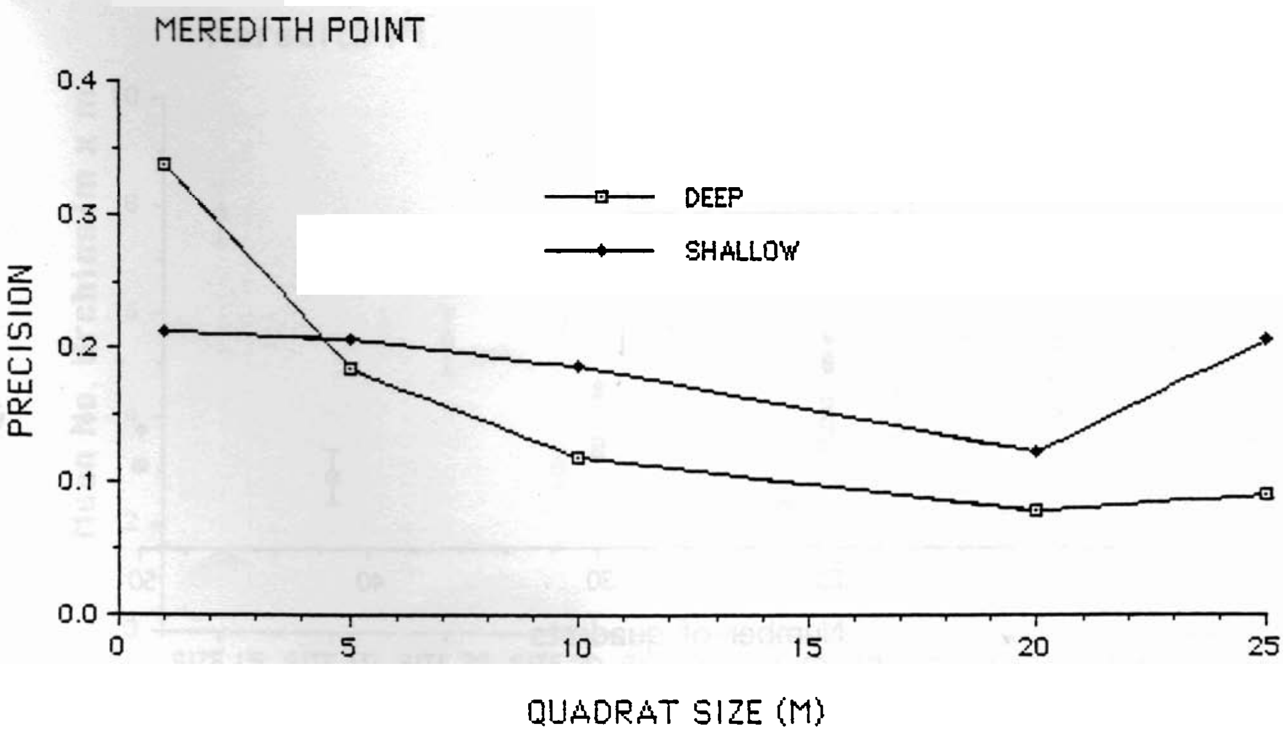
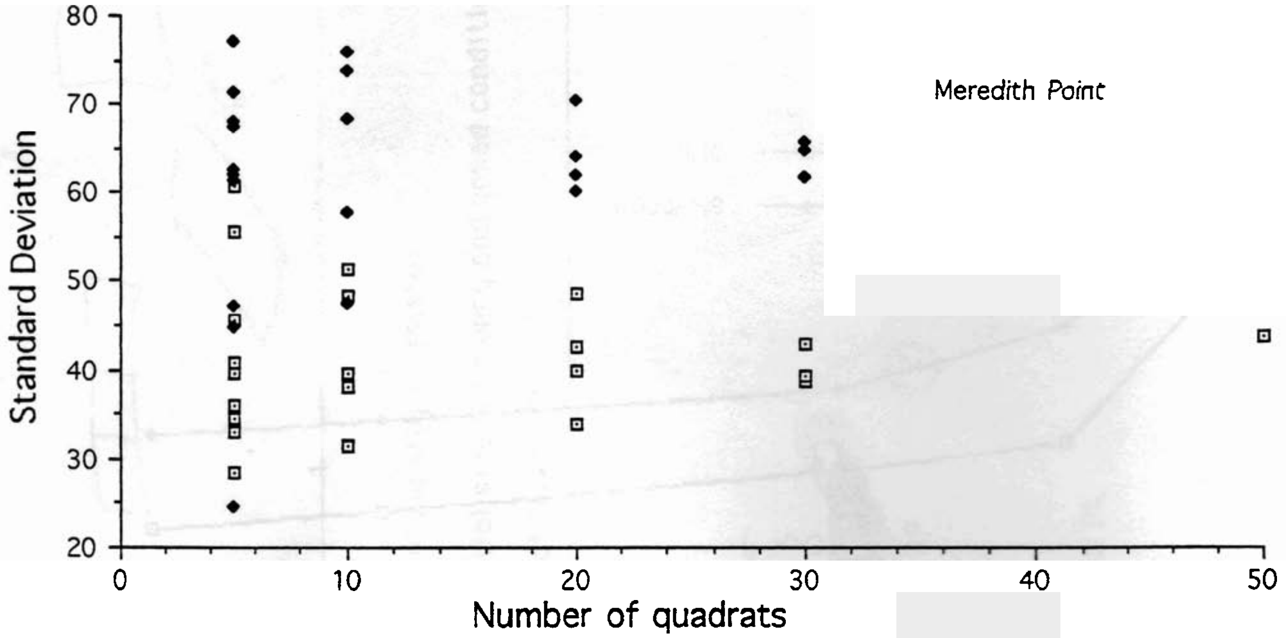


Figure 4

Graphs of standard deviation and standard error as a percentage of the mean versus replication of 5 x 1 m quadrats for both sites.



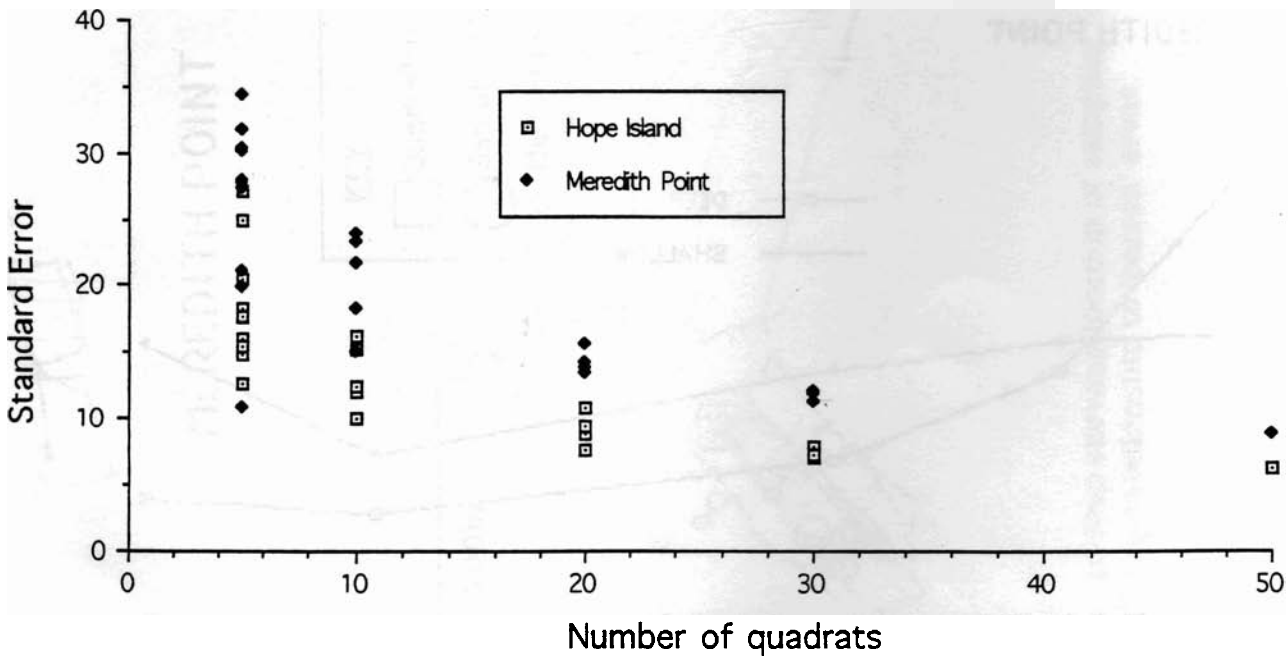
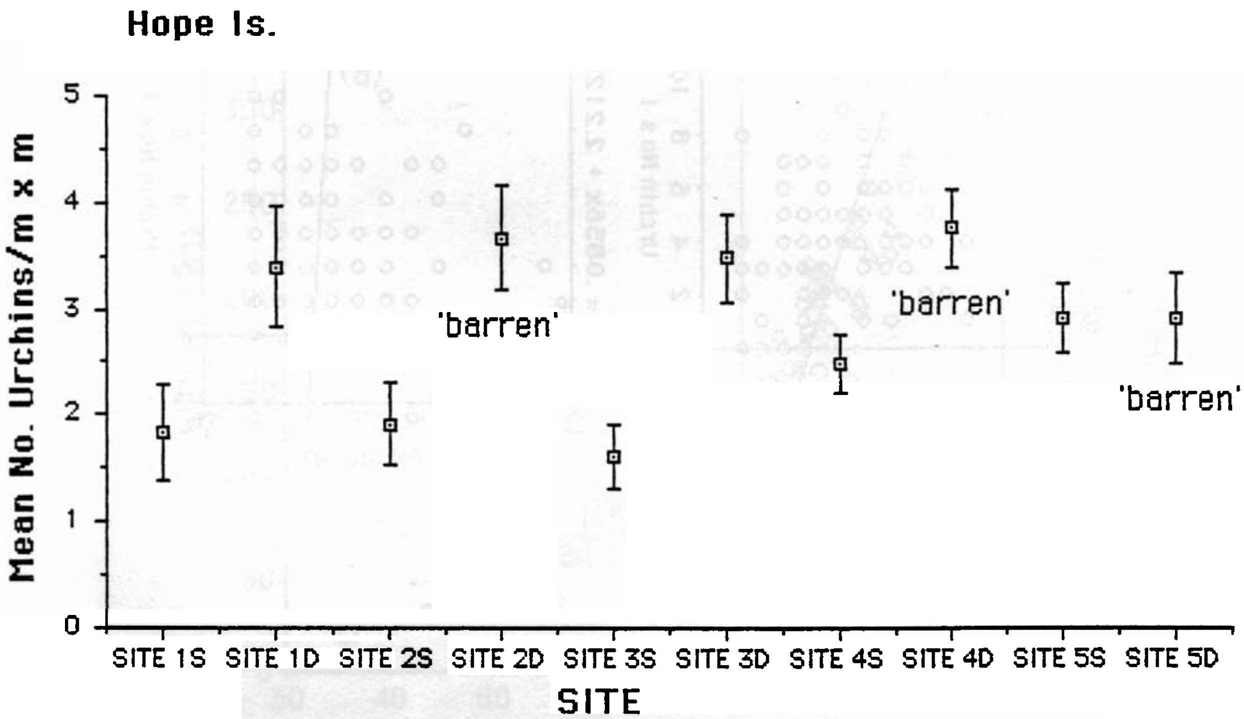


Figure 5

(a) Density of urchins as determined from 1 x 1 m quadrats at sites in the two lease areas. Note that as quadrats were not randomly placed and auto-correlation (Fig 5b) confidence is reduced.



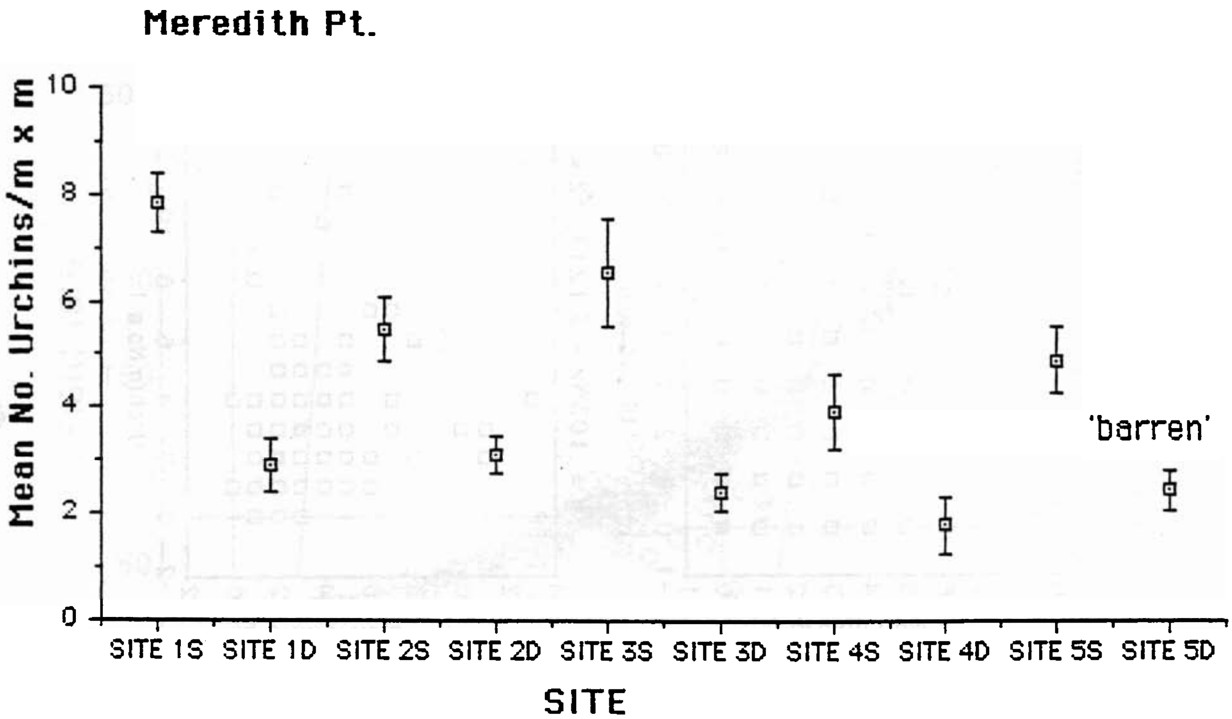


Figure 5(b). Autocorrelation between succesive (1 x 1m) quadrats at both sites.

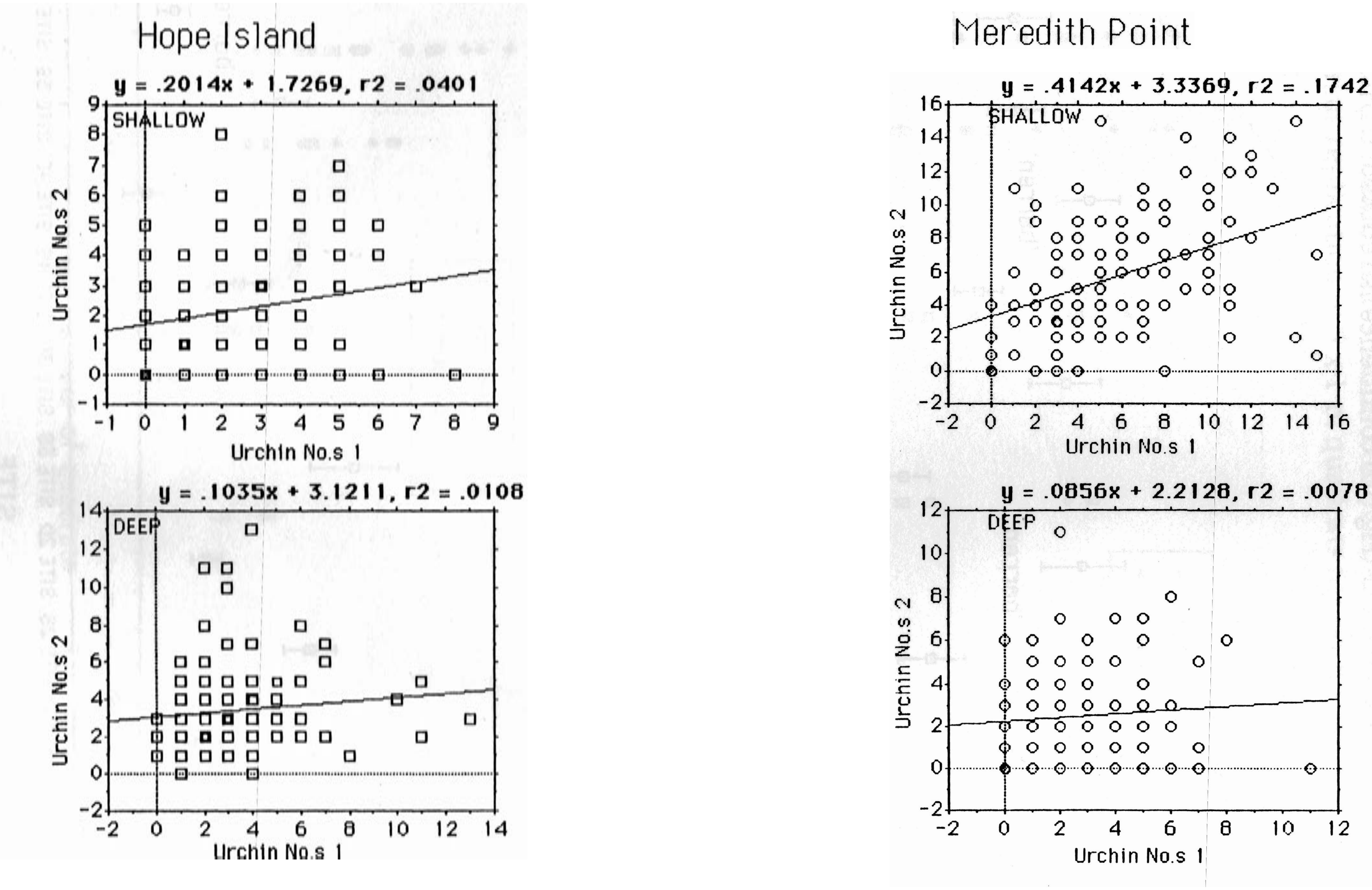


Figure 5(b). Autocorrelation between succesive (1 x 1m) quadrats at both sites.

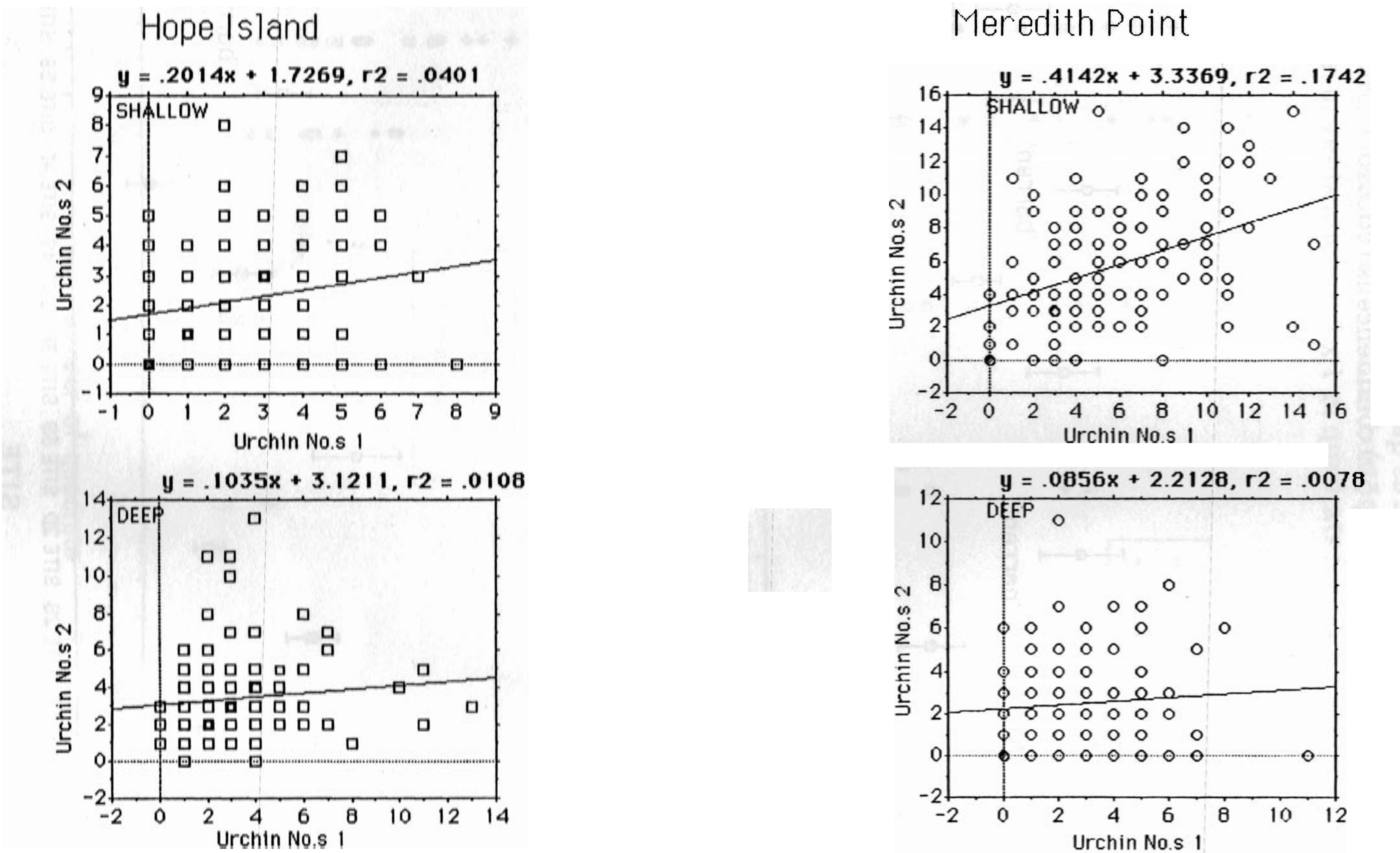
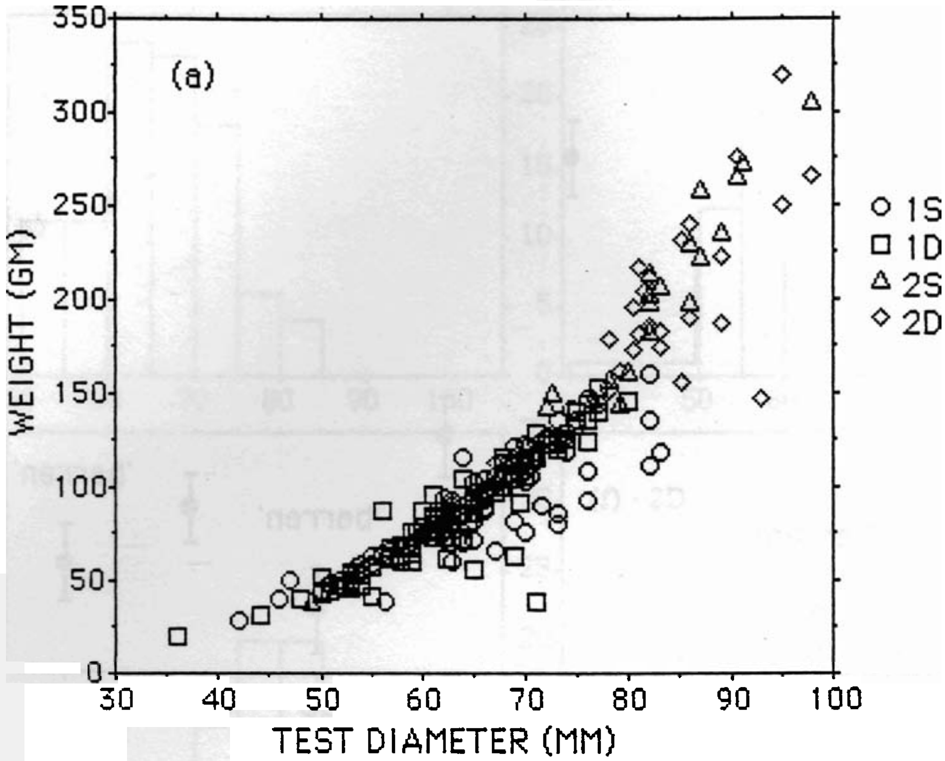


Figure 6

Urchin wet weight versus diameter for individual sites (a) and for all sites (b).

HOPE ISLAND DATA, SAMPLED:15.7.93



y = 117.203 - 4.828x + .068x2

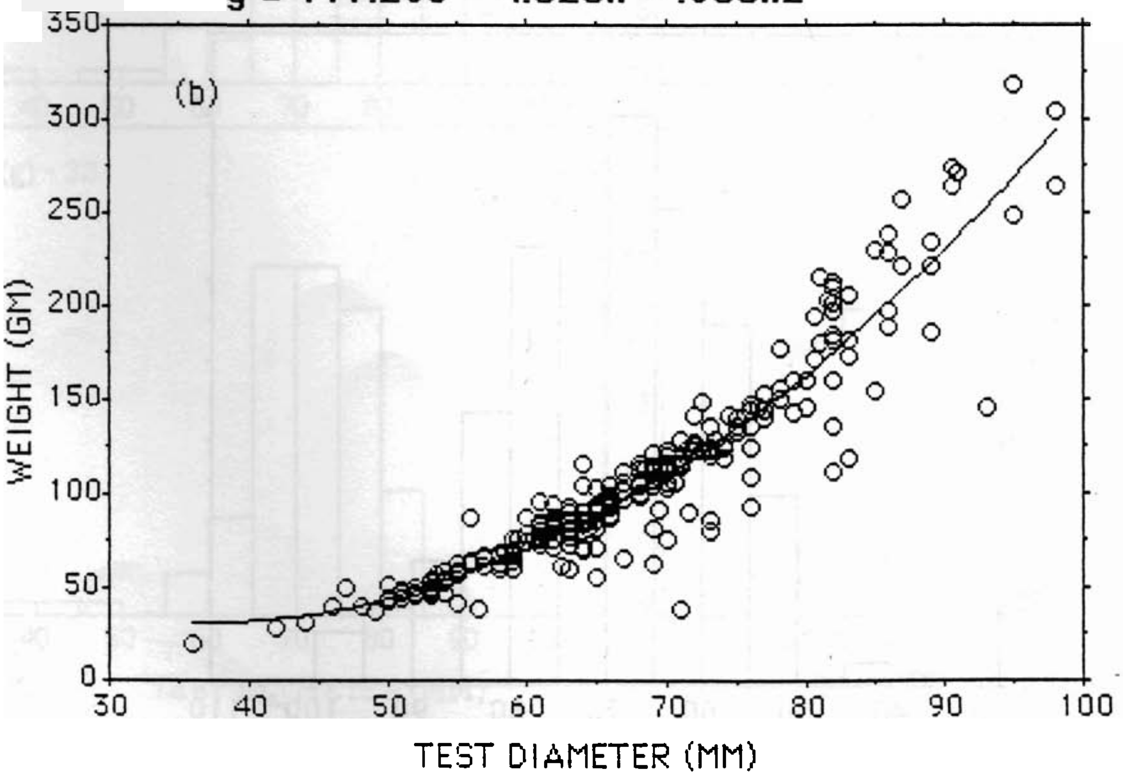
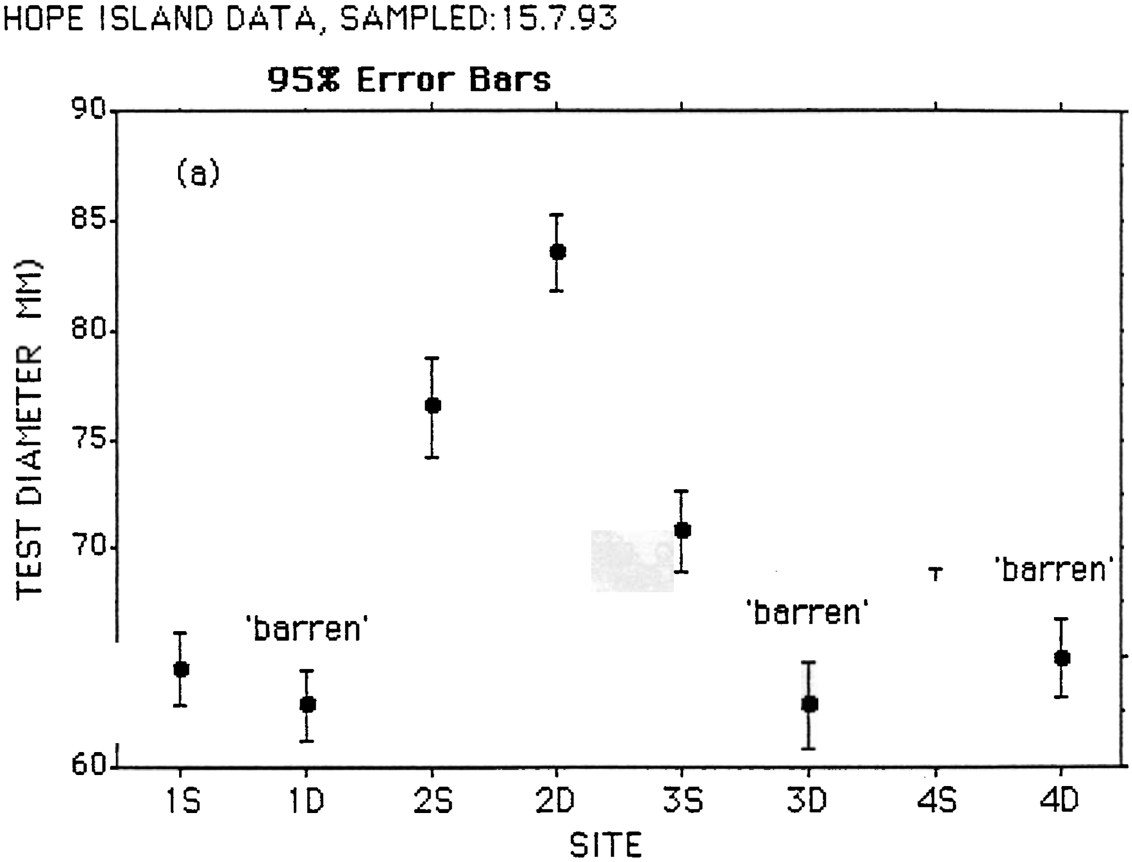


Figure 7.

Mean test diameter for the sites at Hope Island with a breakdown of sizes for all sites (6c) and for each site (6 c-j).



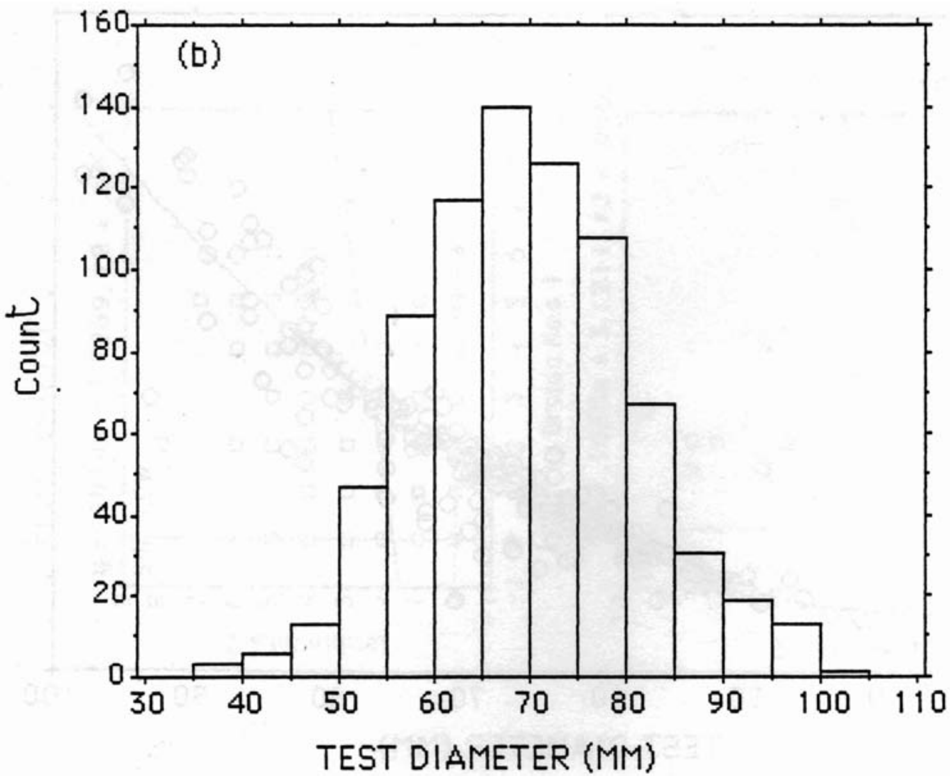


Figure 7 (c-h) Breakdown of urchin diameters for each site.

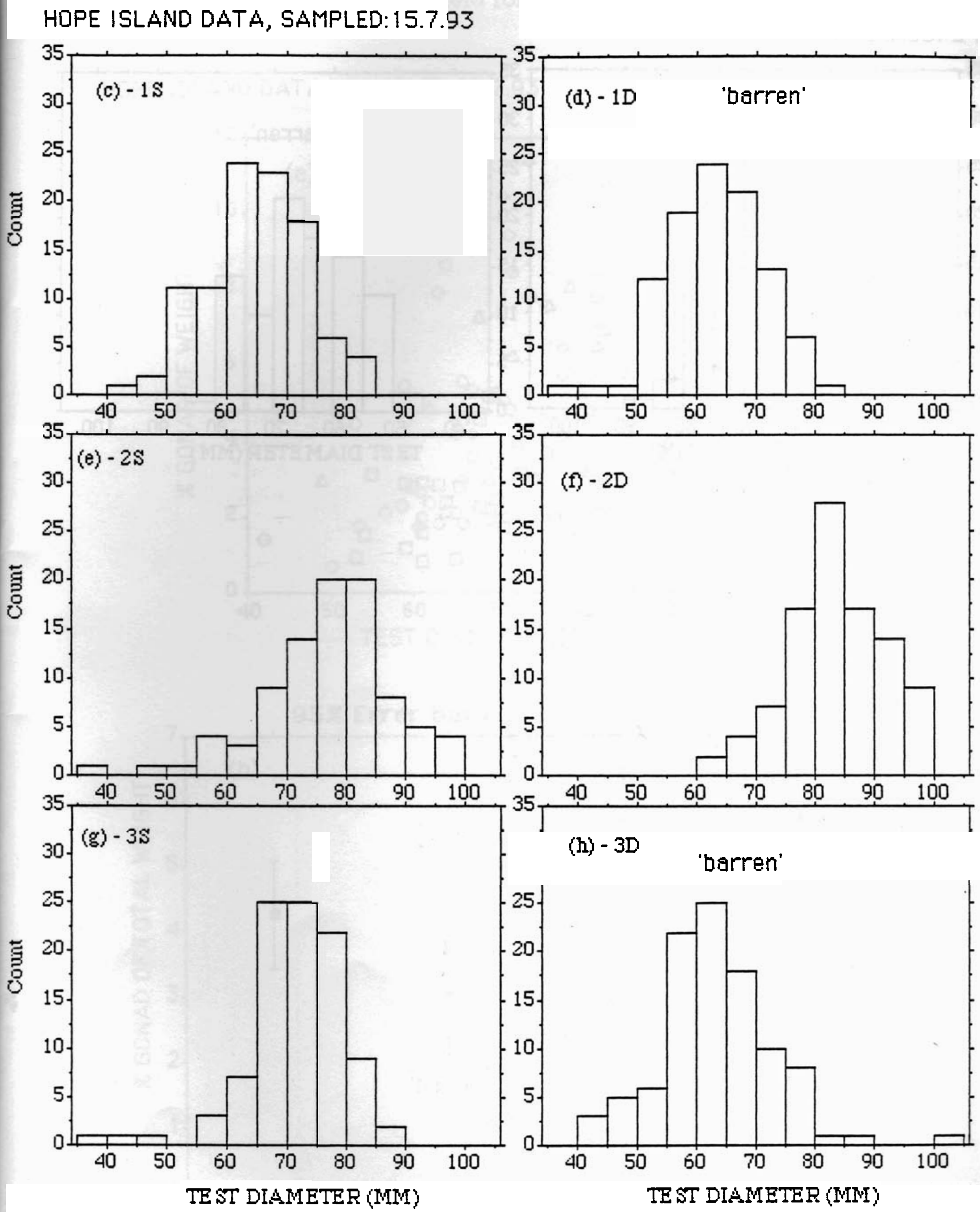


Figure 7 (i-j) Breakdown of urchin diameters for each site

HOPE ISLAND DATA, 15.7.93

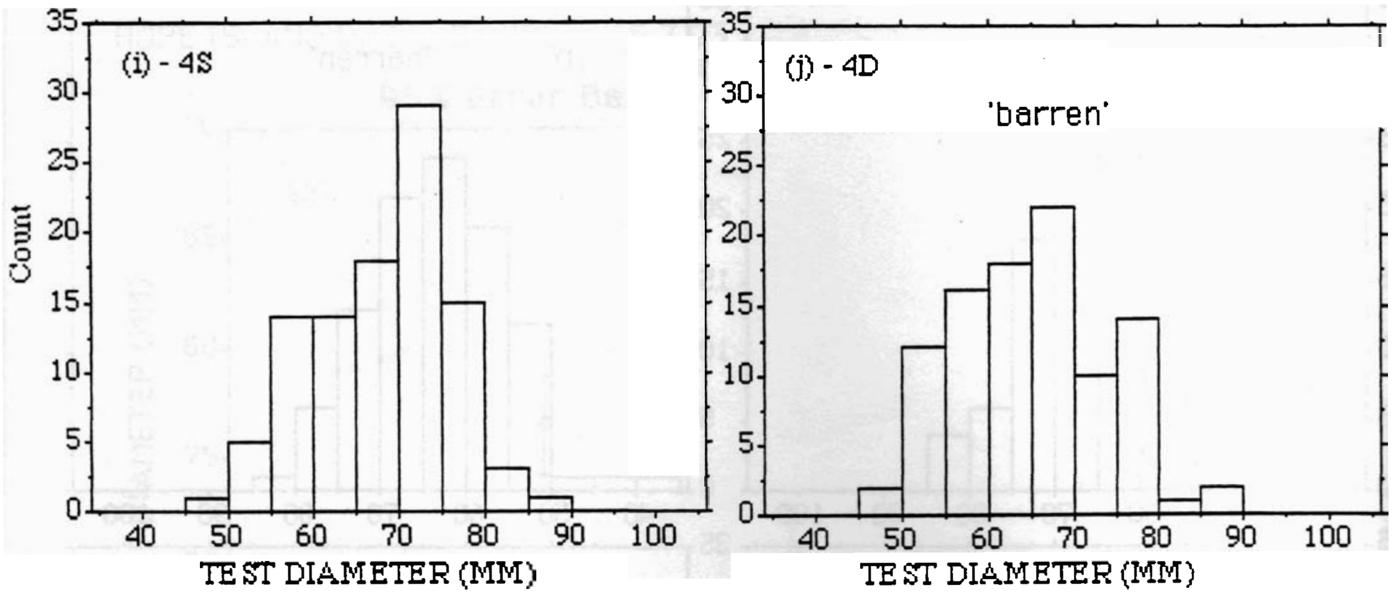
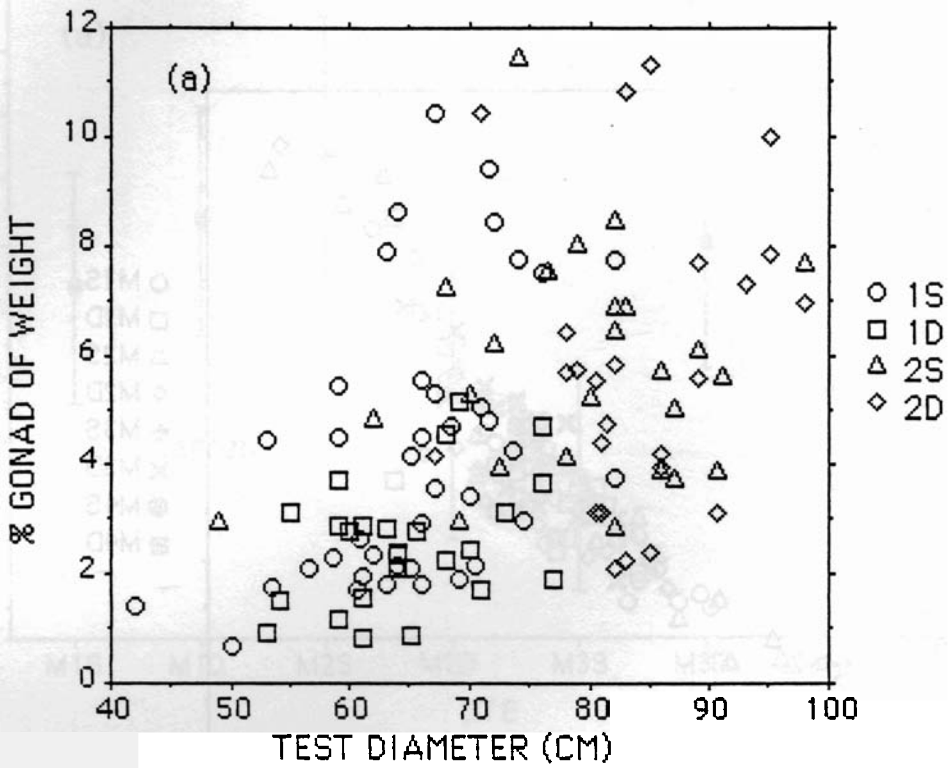


Figure 8

Test diameter versus gonad yield for all sites (a) and mean values for each site (b).

HOPE ISLAND DATA, SAMPLED:15.7.93



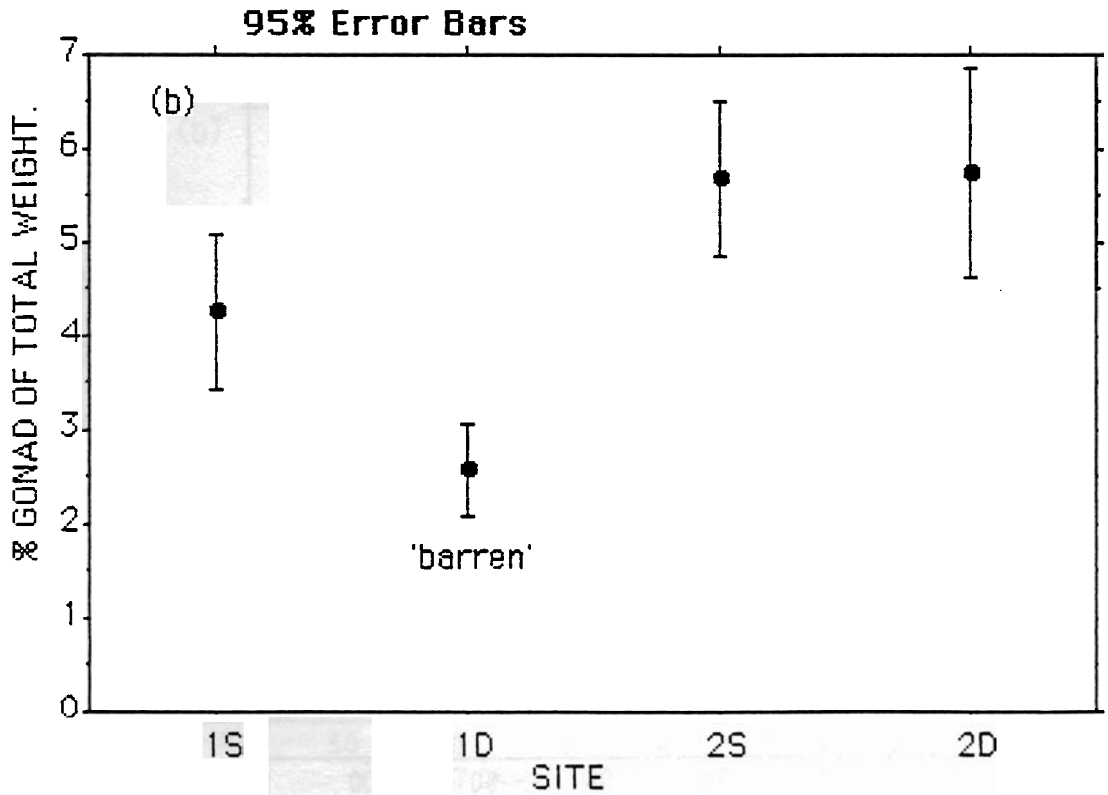
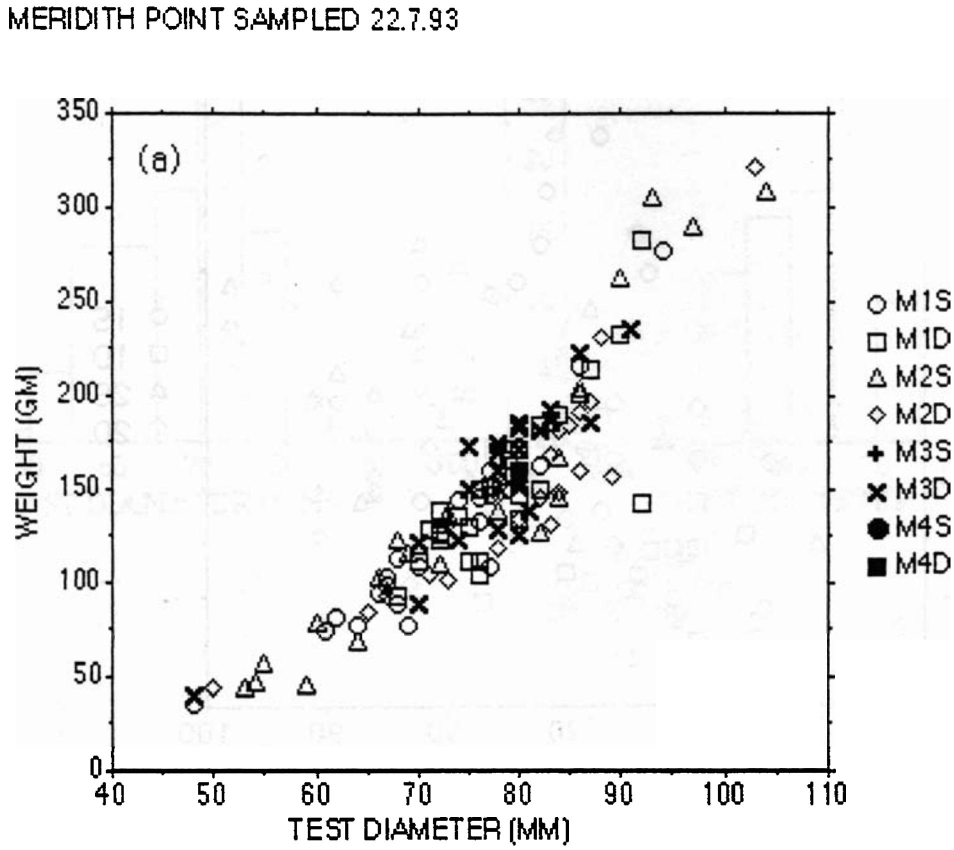


Figure 12

Wet weight versus diameter for individual sites (a) and for all sites (b).



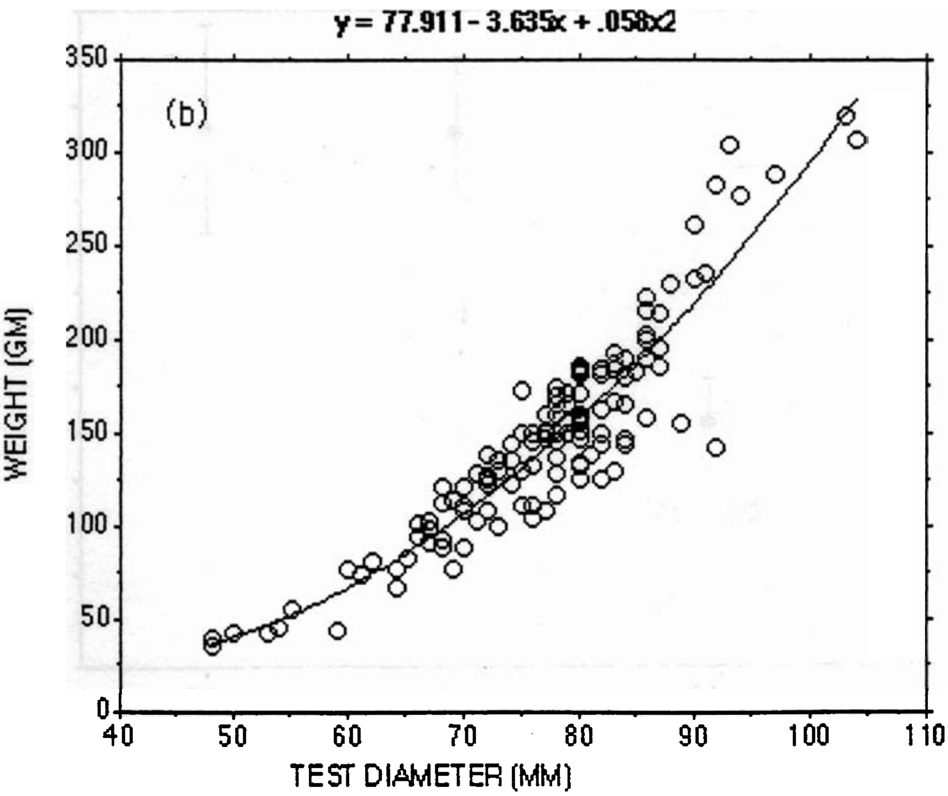
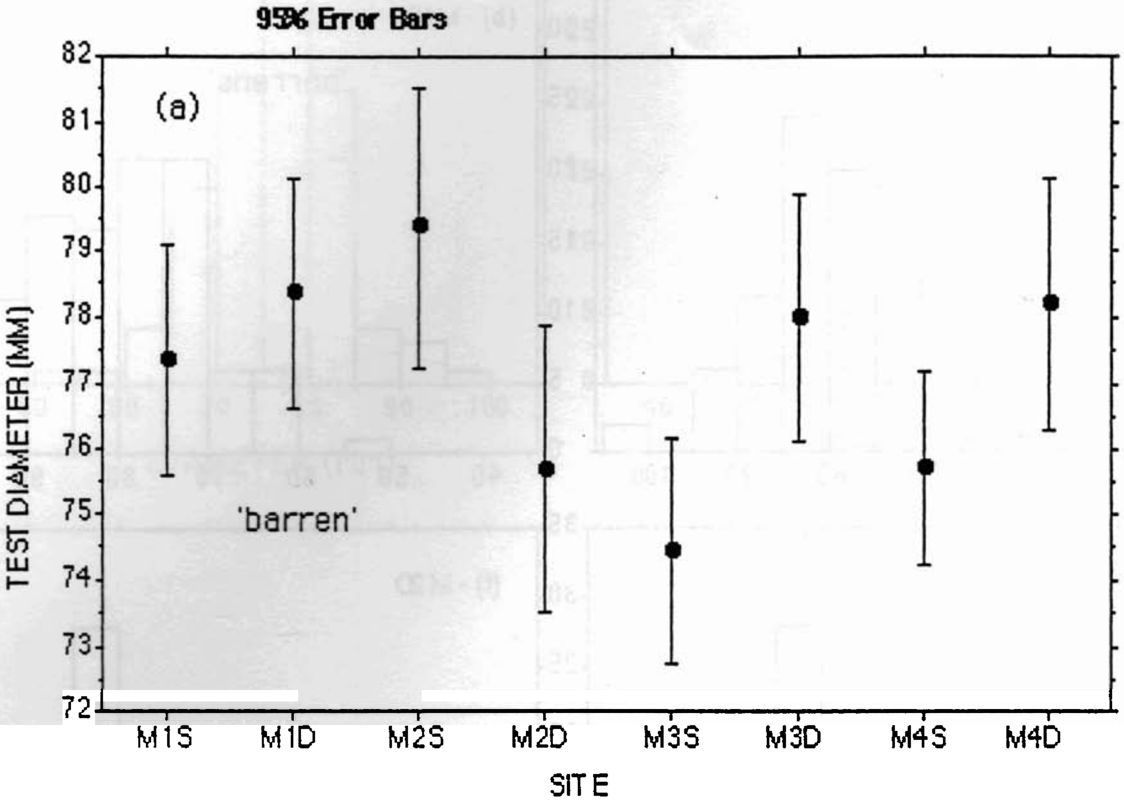
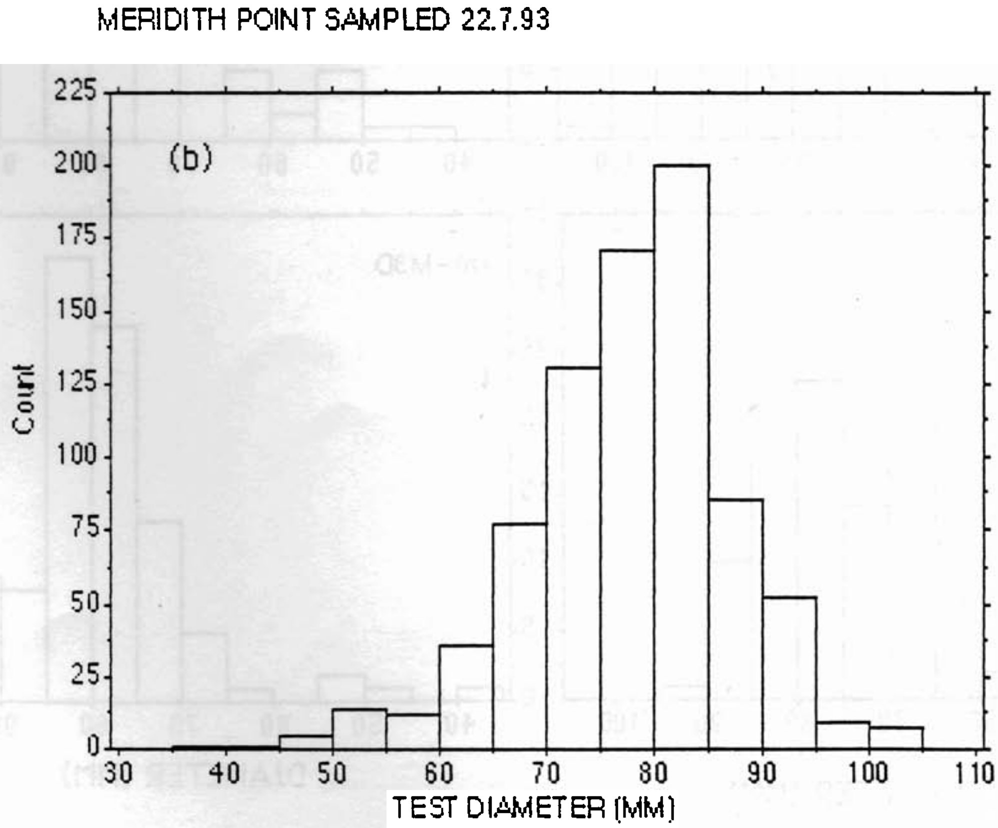


Figure 11.

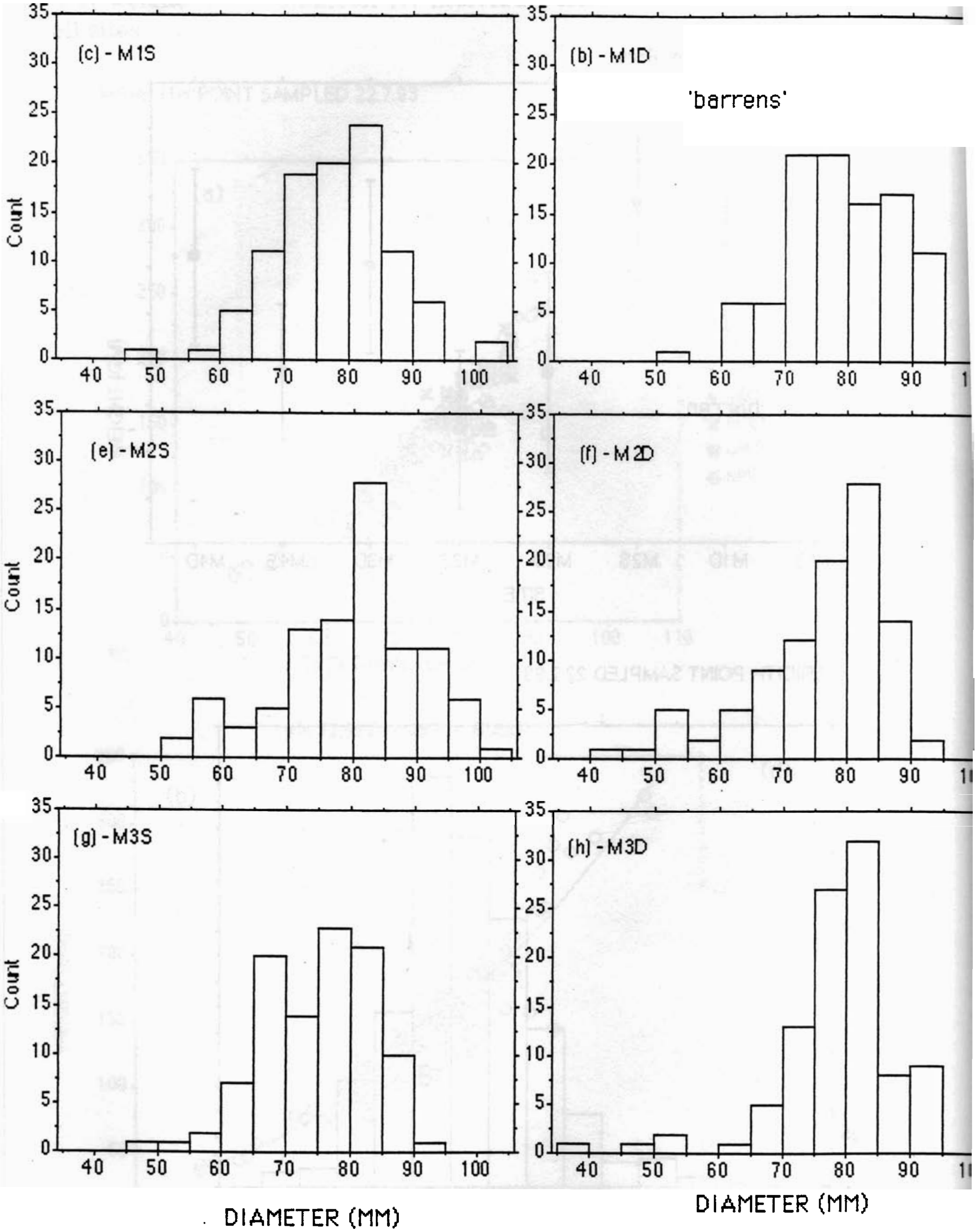
Mean test diameter for the sites at Meredith Pt (11a) with a breakdown of sizes for all sites (11b) and for each site (11 c-j).





Figures 13 c-j, breakdown of urchin diameters for each site (n=100, for each sample).

MEREDITH POINT SAMPLED 22.7.93.



Figures 13 c-j, breakdown of urchin diameters for each site continued.

MEREDITH POINT SAMPLED 22.7.93.

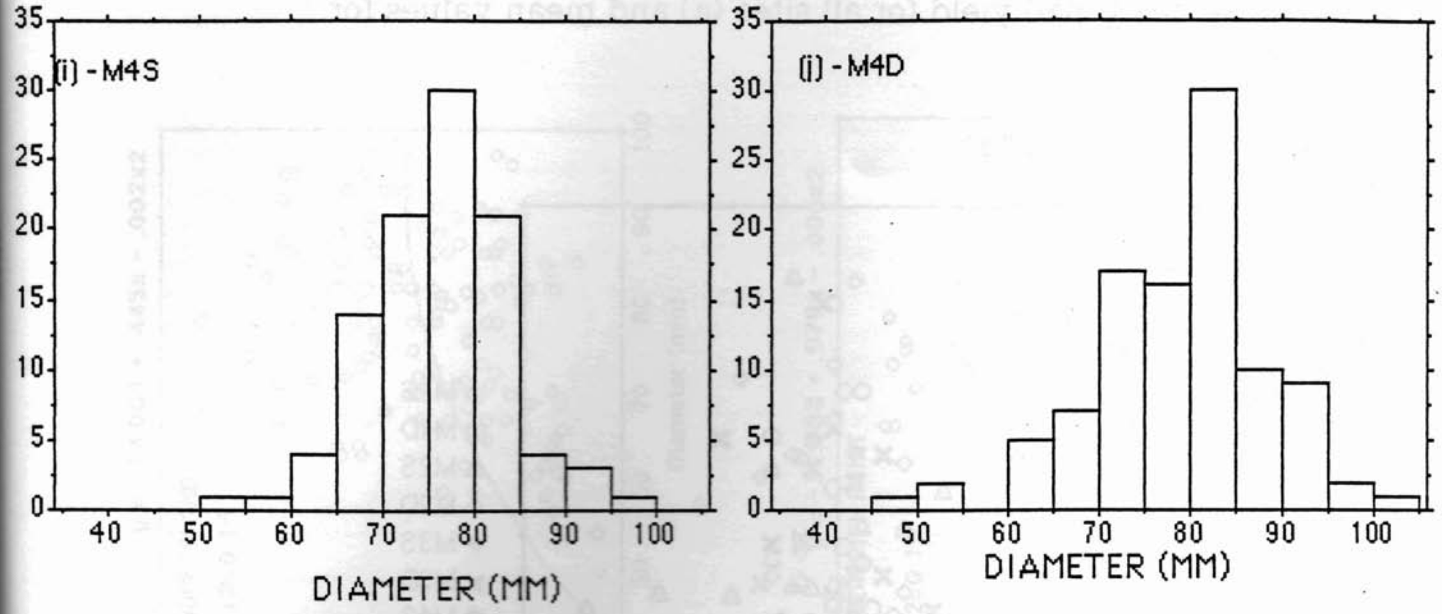
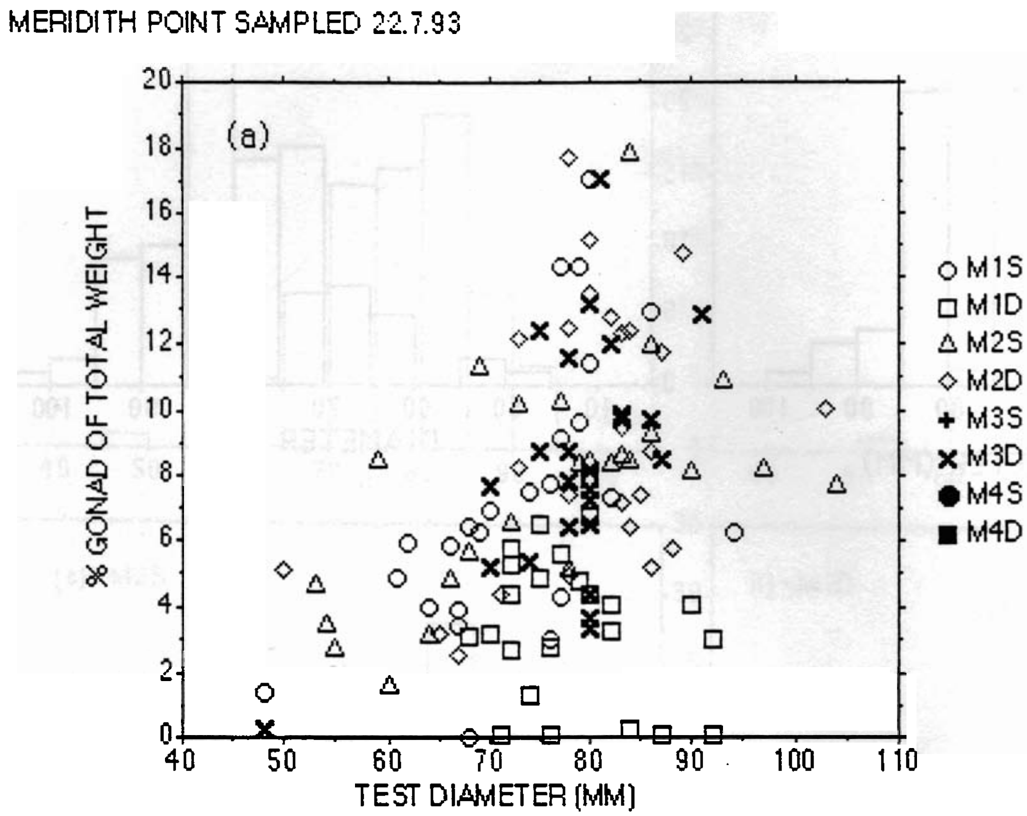


Figure 12

Test diameter versus gonad yield for all sites (a) and mean values for each site (b).



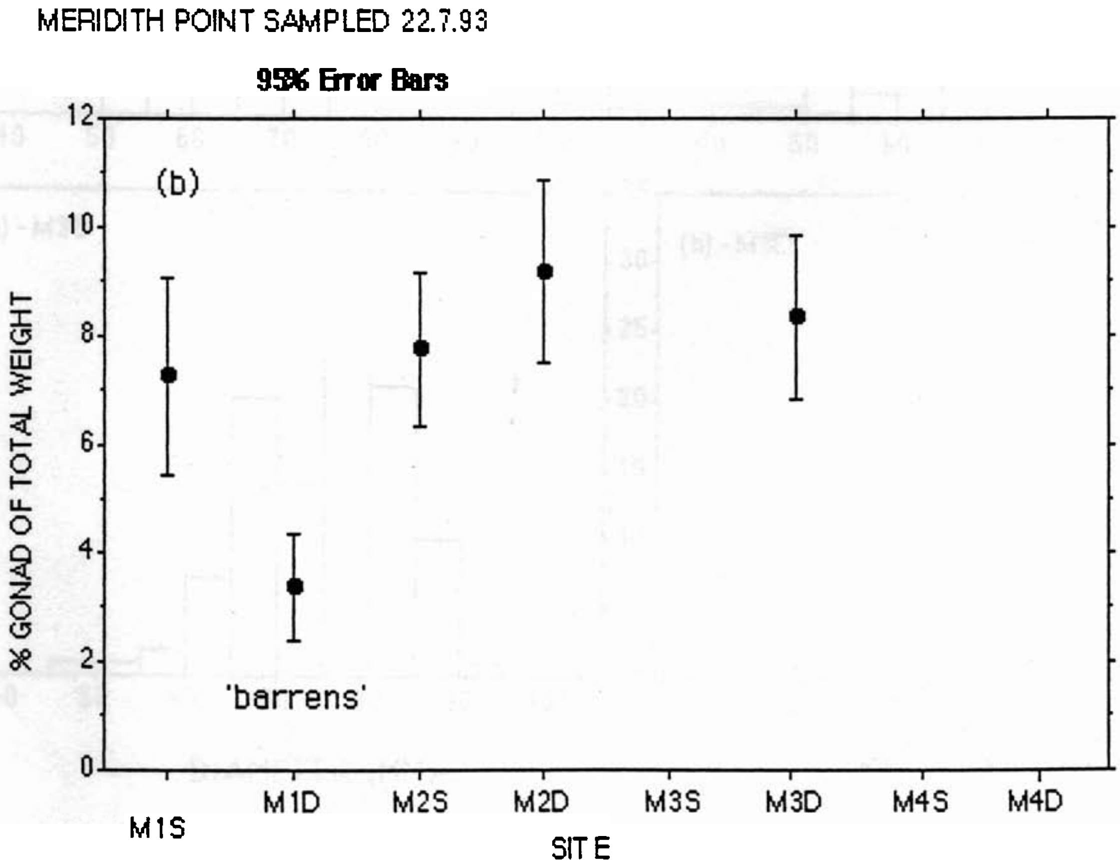


Fig 13 Lines of best fit for % gonad for (a) all sites and (b) sites not within barrens.

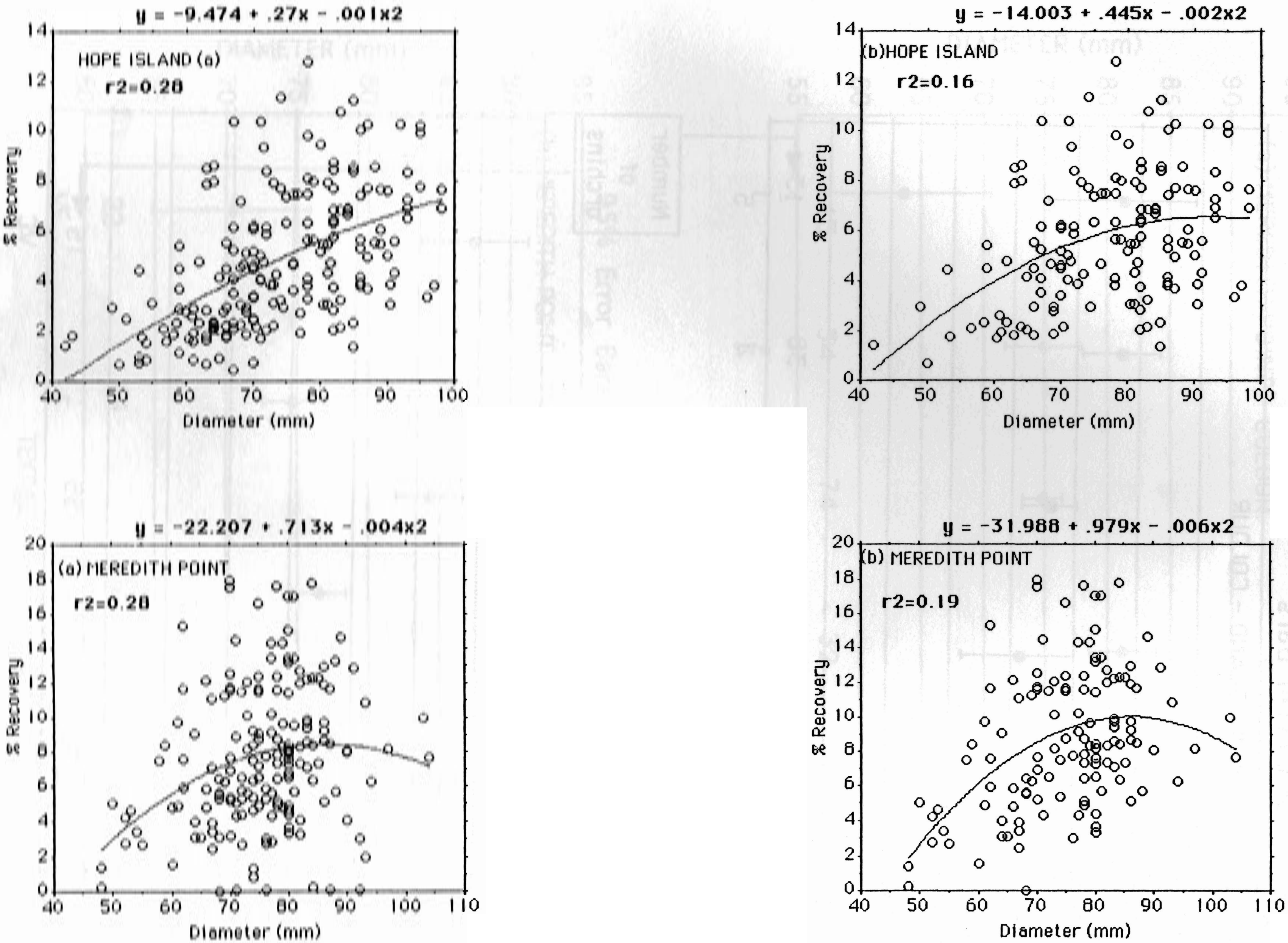


FIGURE 14 Graphs of mean diameter versus (a) colour and (b) texture for all sites at Hope Island.

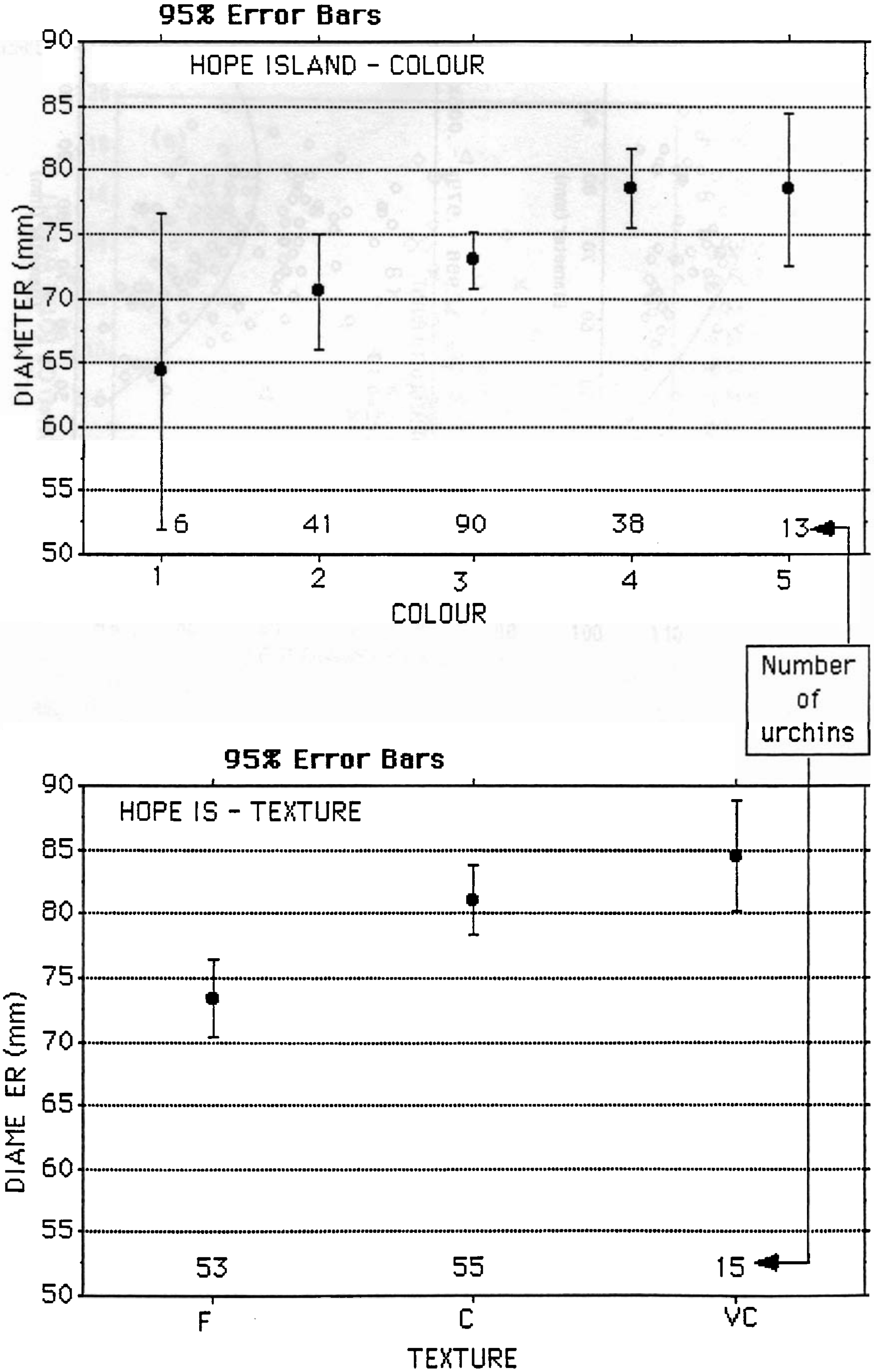
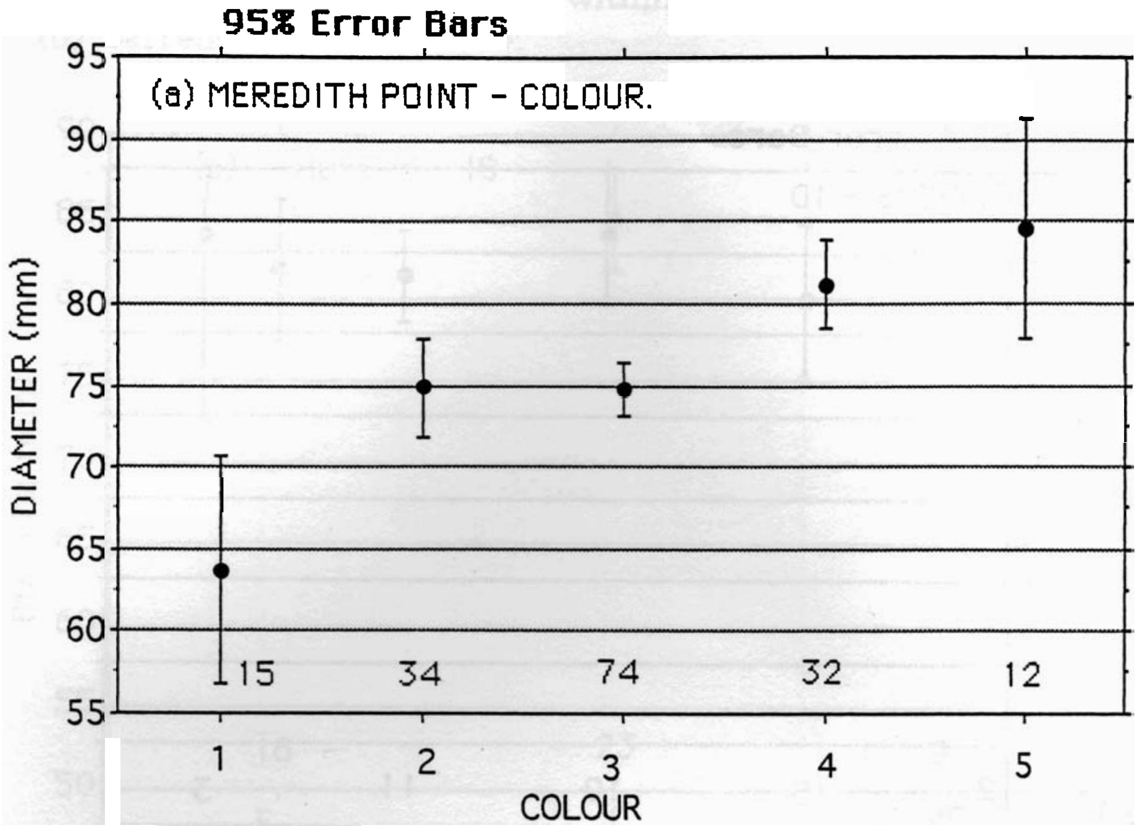


FIGURE 15 Graphs of mean diameter versus (a) colour and (b) texture for all sites at Meredith Point.



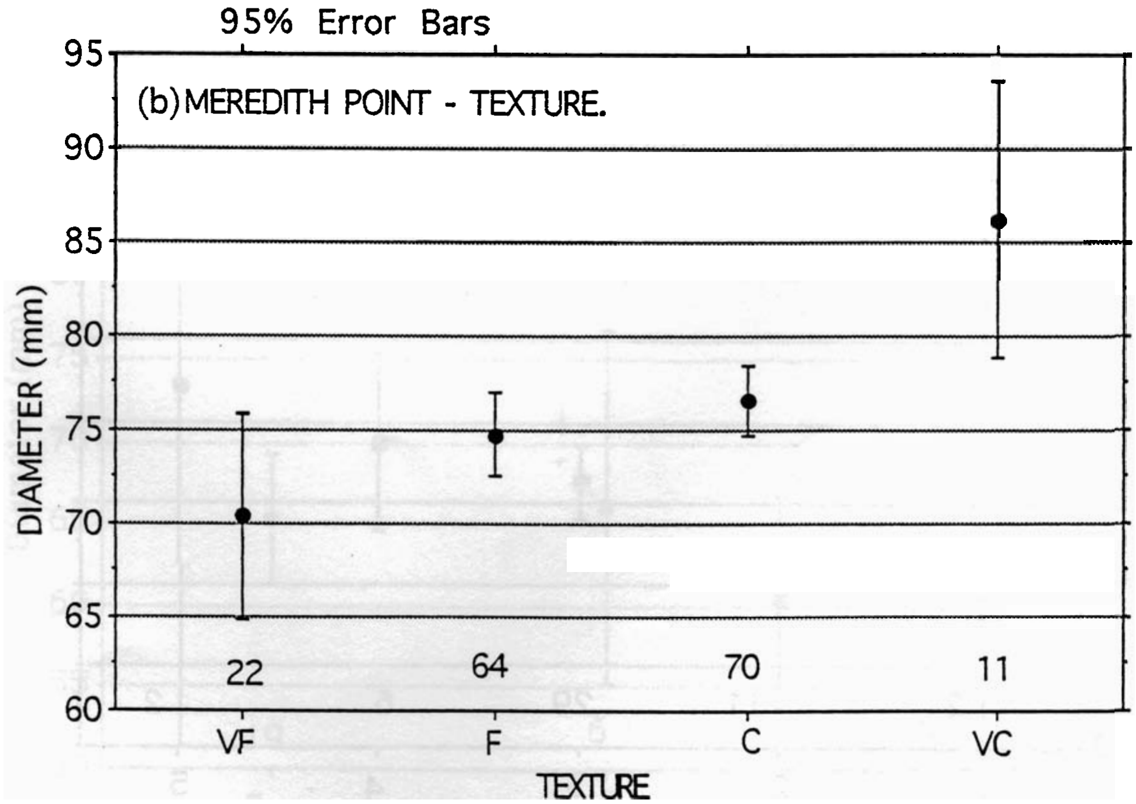
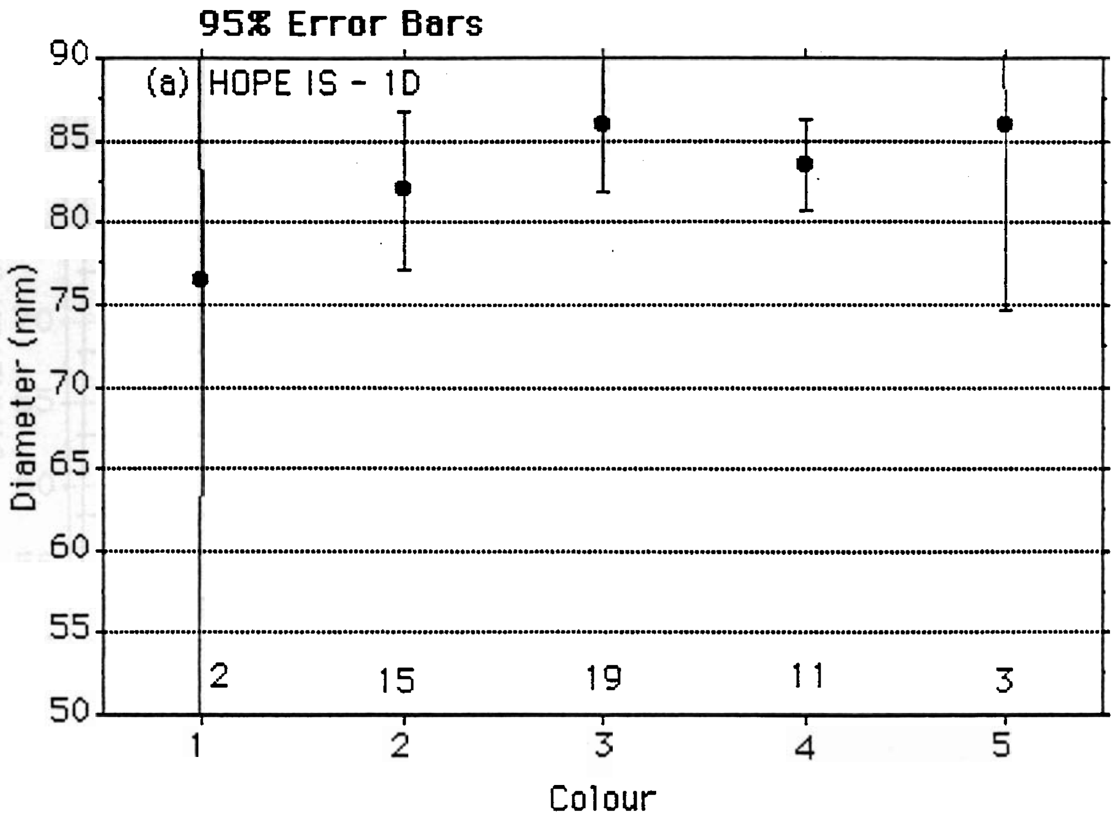


Figure 16 Comparison of sites within Hope Is (a) vegetated area (b) 'barrens' area for colour.



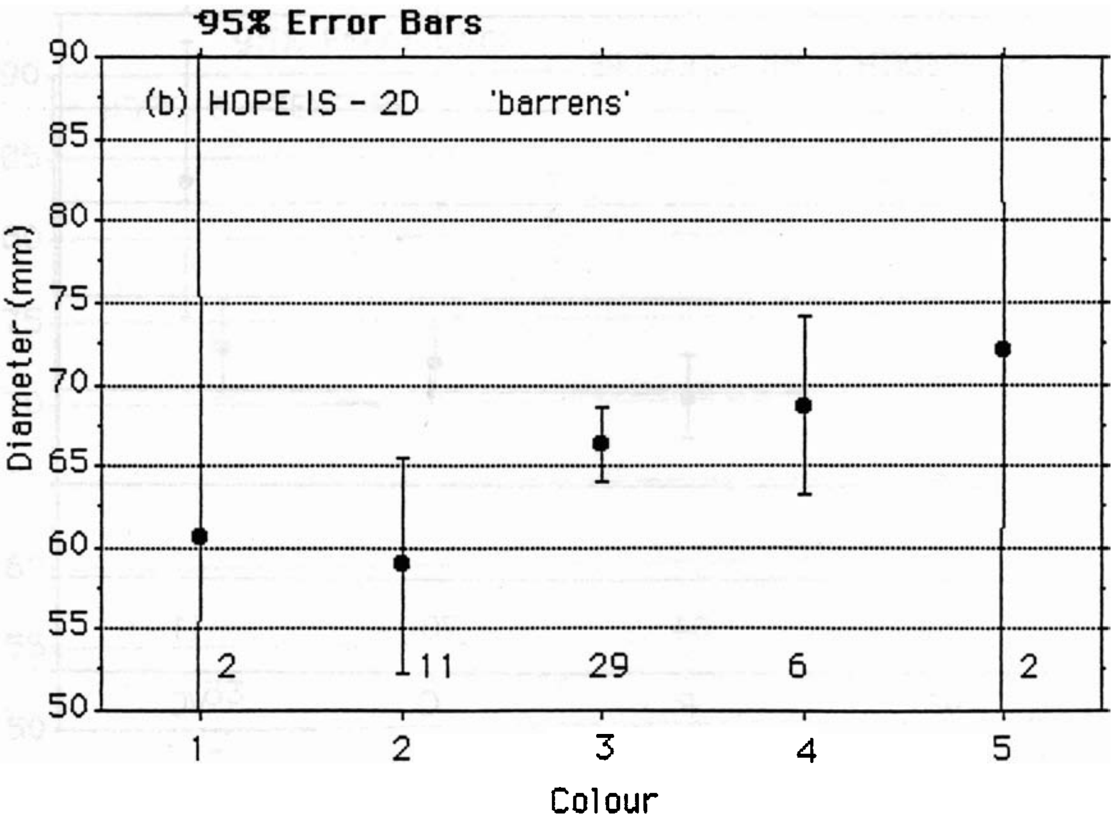
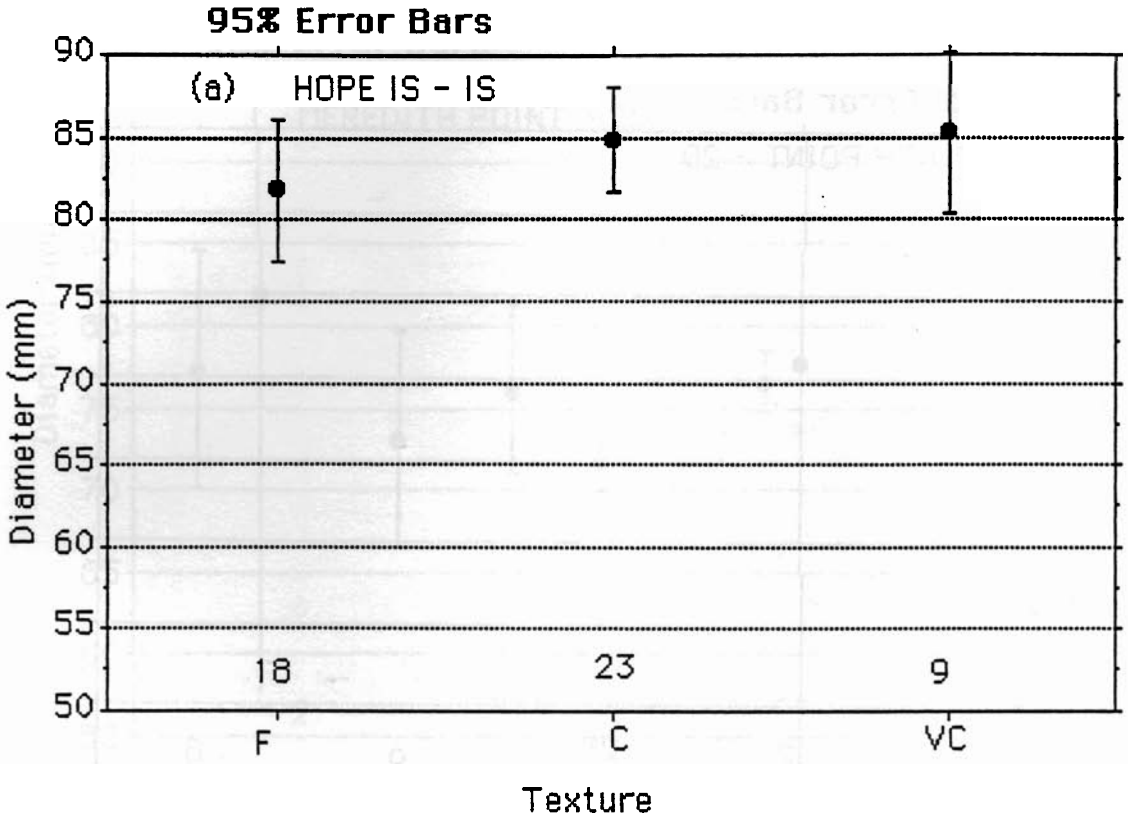


Figure 17 Comparison of sites within Hope Is (a) vegetated area (b) 'barrens' area for texture.



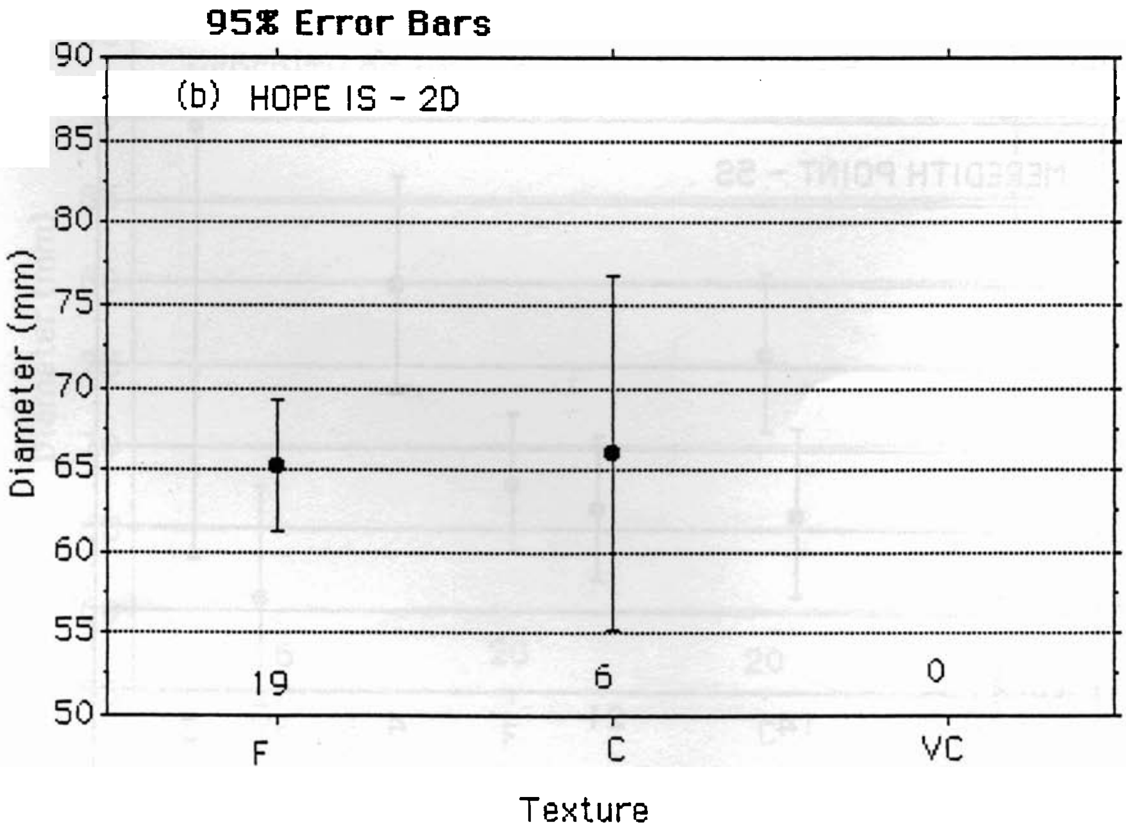


Figure 17 Comparison of sites within Meredith Point for (a) vegetated area and (b) 'barrens' area for colour.

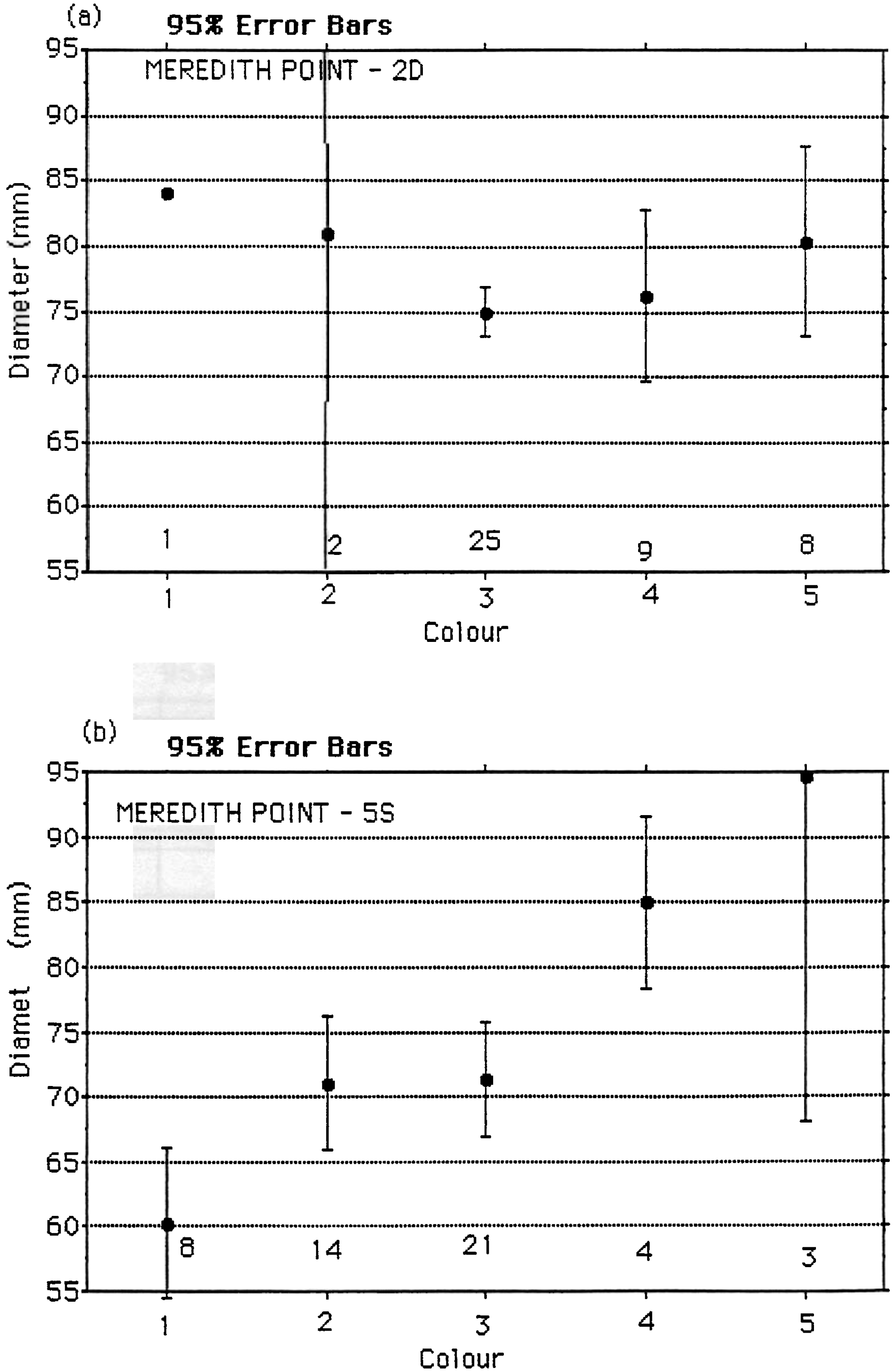
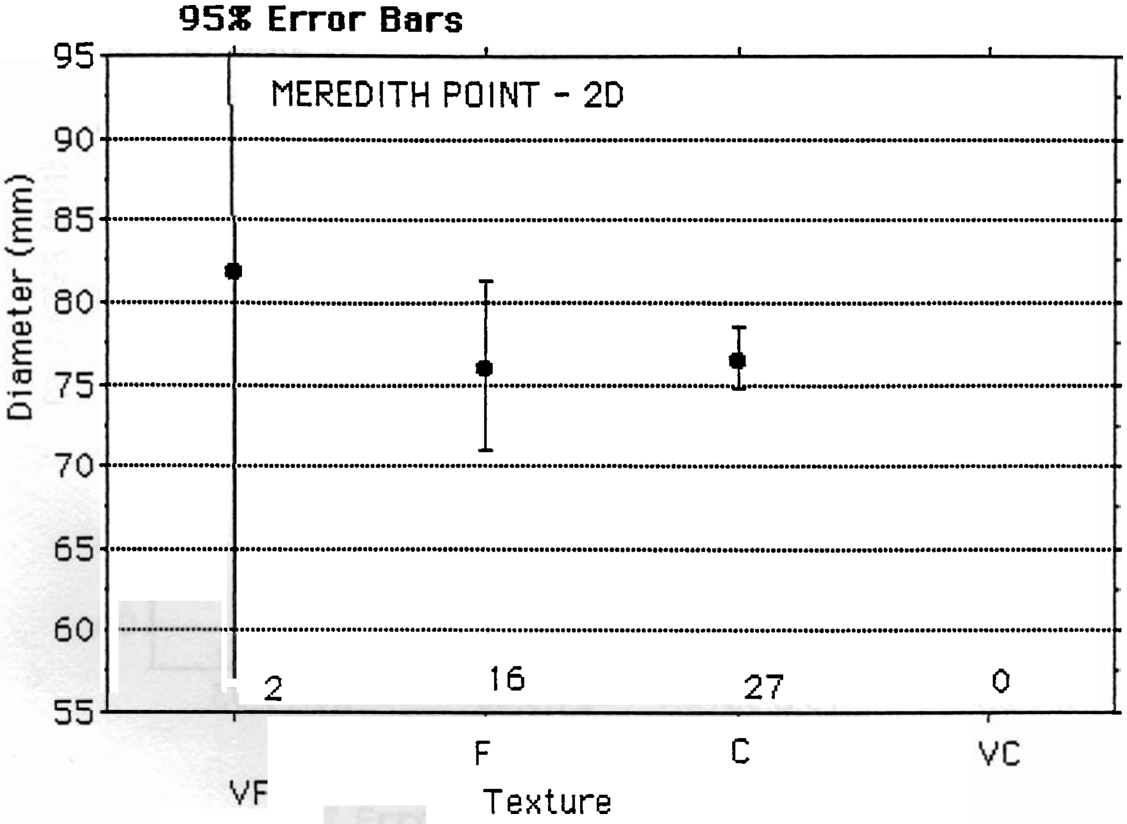


Figure 18 Comparison of sites within Meredith Point for (a) vegetated area and (b) 'barrens' area for texture.



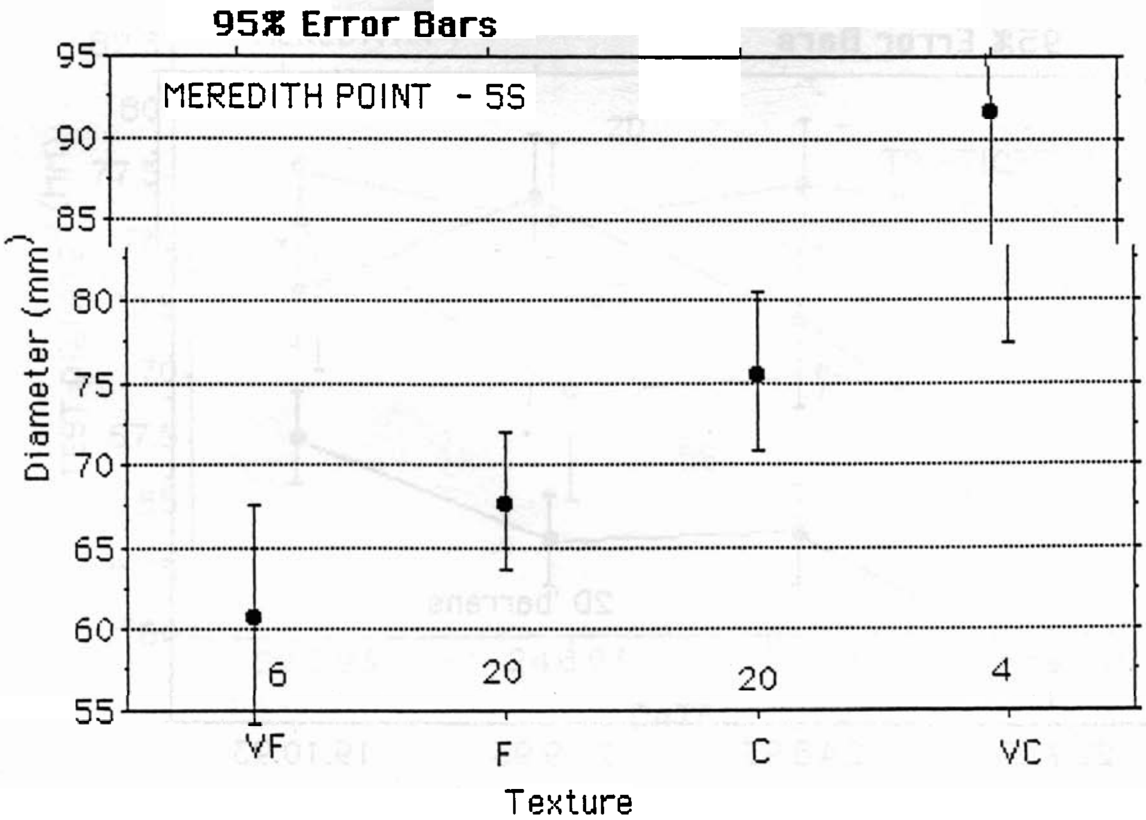
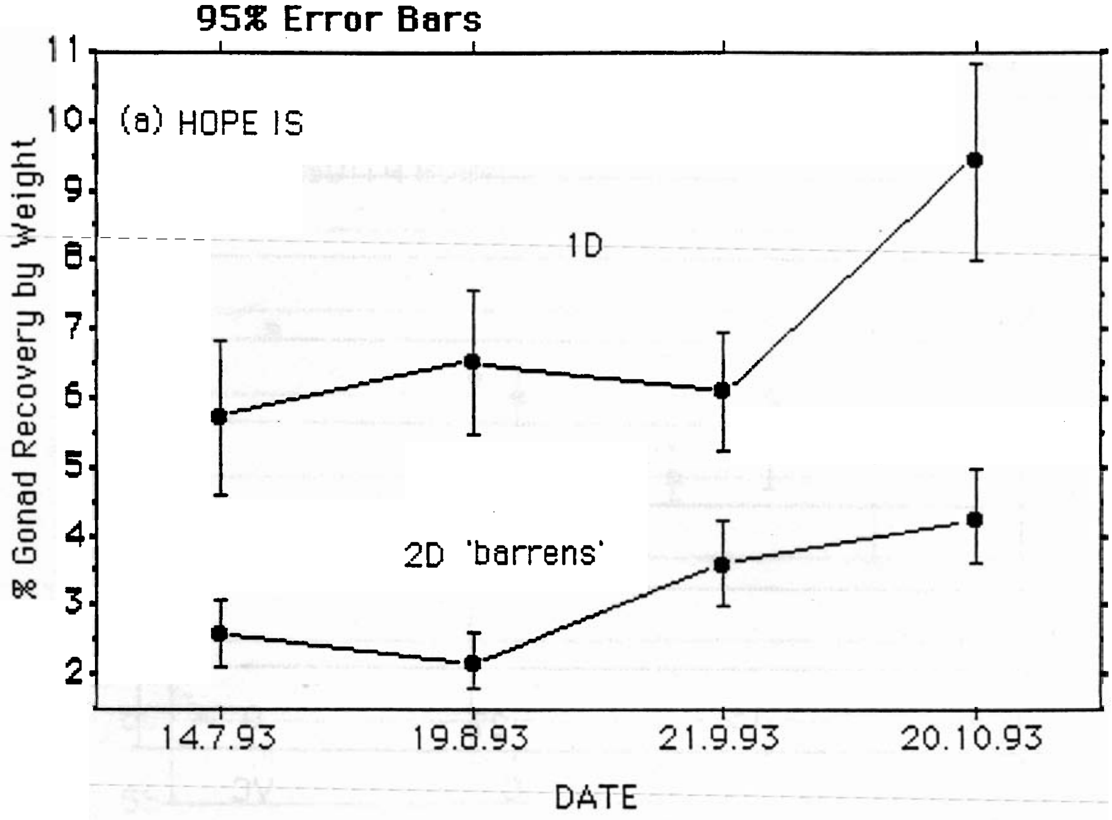


FIGURE 19 (a &b) Graph of mean percentage recovery of roe for a barren area and a vegetated area and (c&d) mean diameter of processed urchins at both sites for July to October 1993



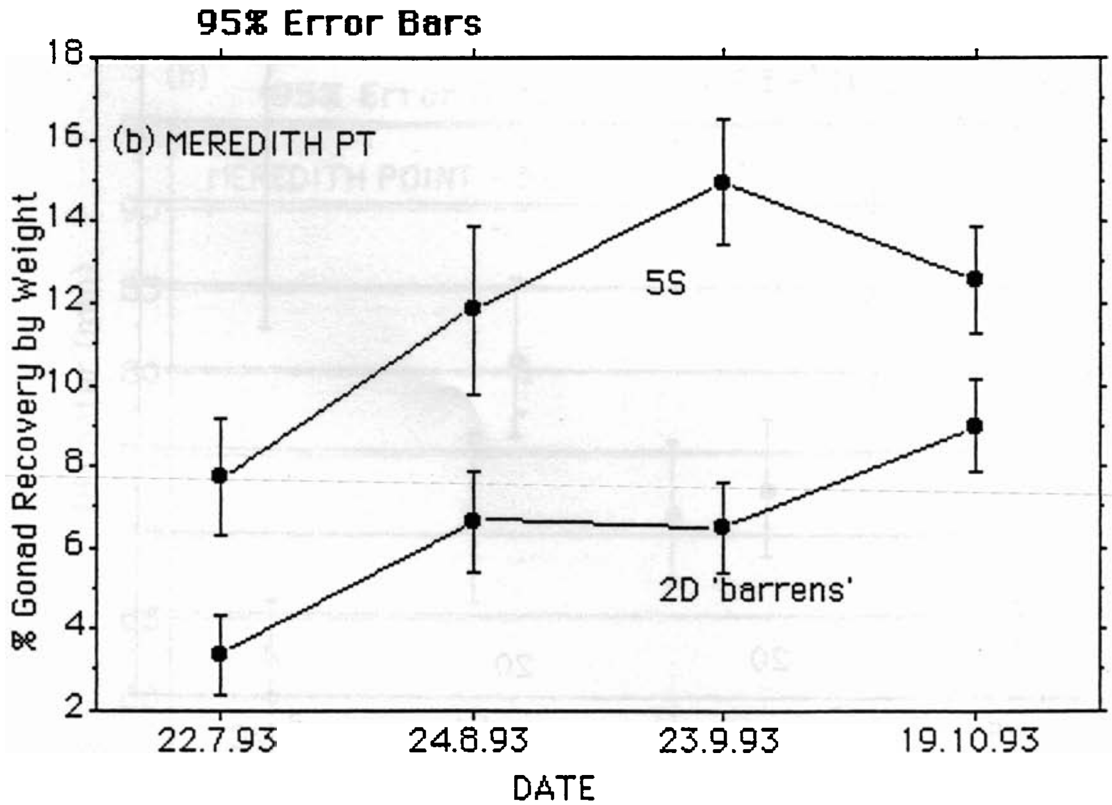
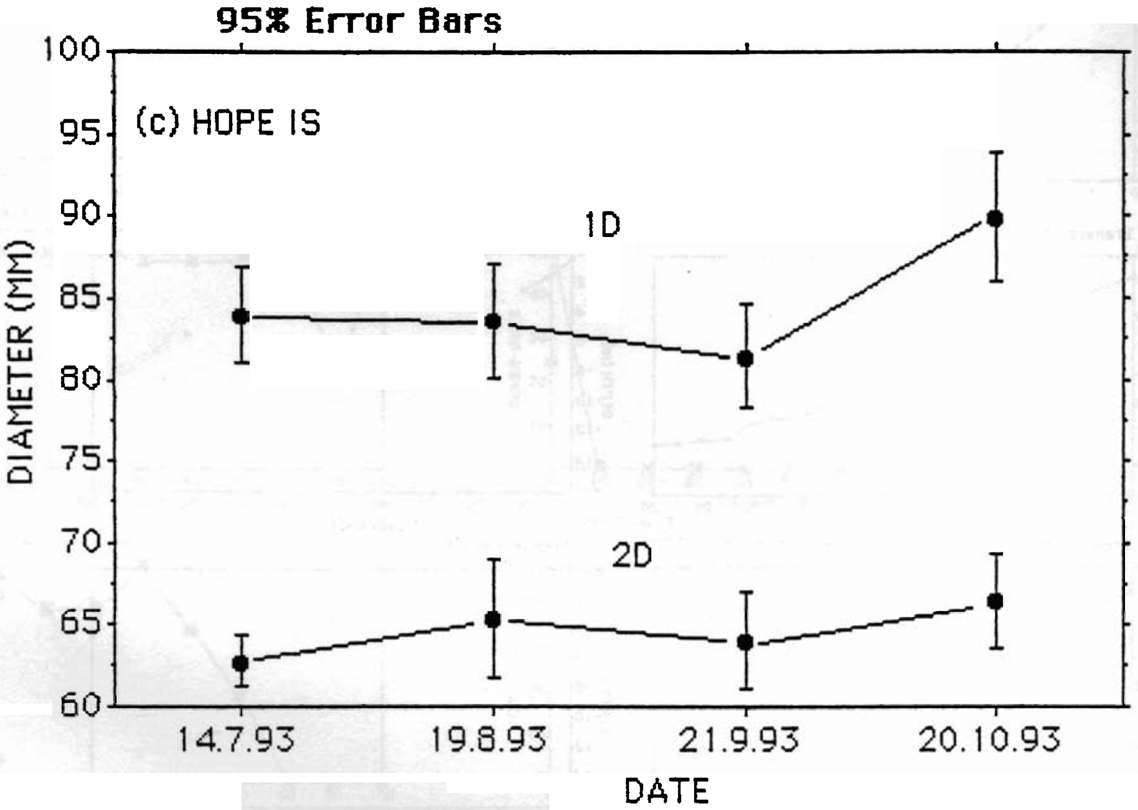


FIGURE 19 (c&d) Mean diameter of processed urchins from monthly samples, 25 urchins in each sample and 1D, 2D, 2D and 5S refer to location with respect to transect numbers.



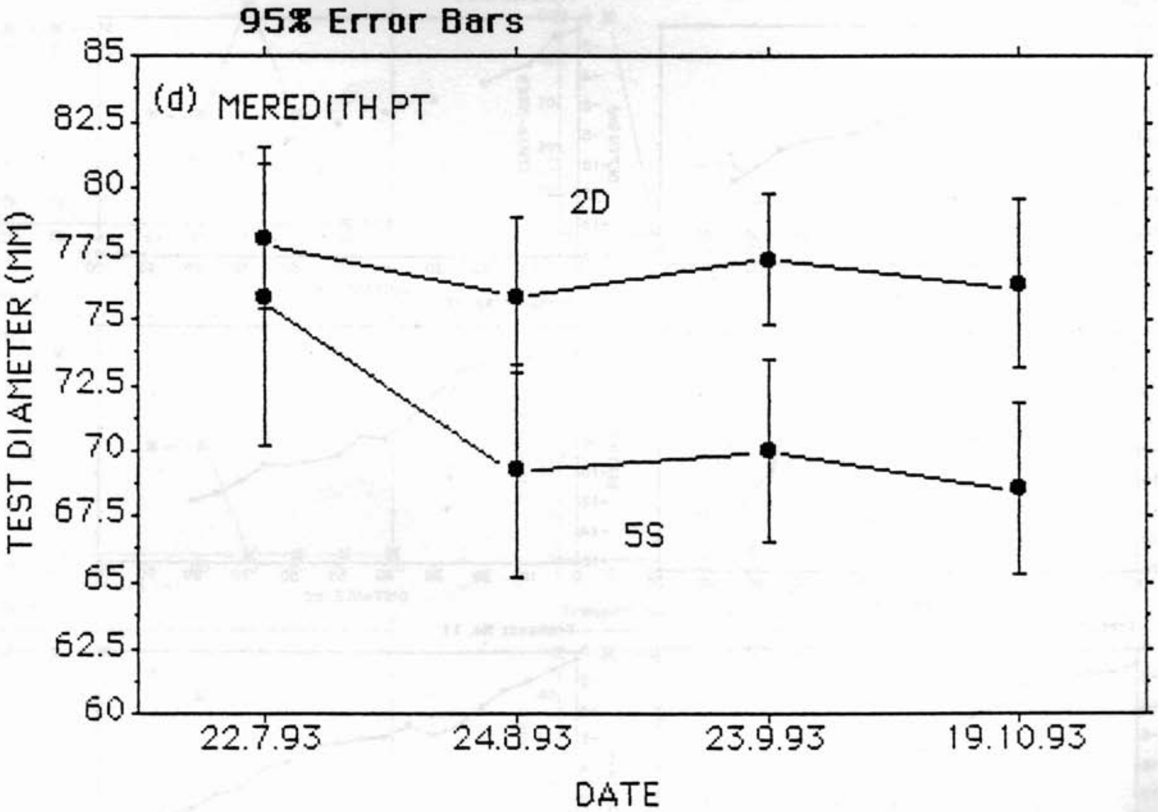


FIGURE 21 Graphs of distance versus depth for each transect at Hope Island.

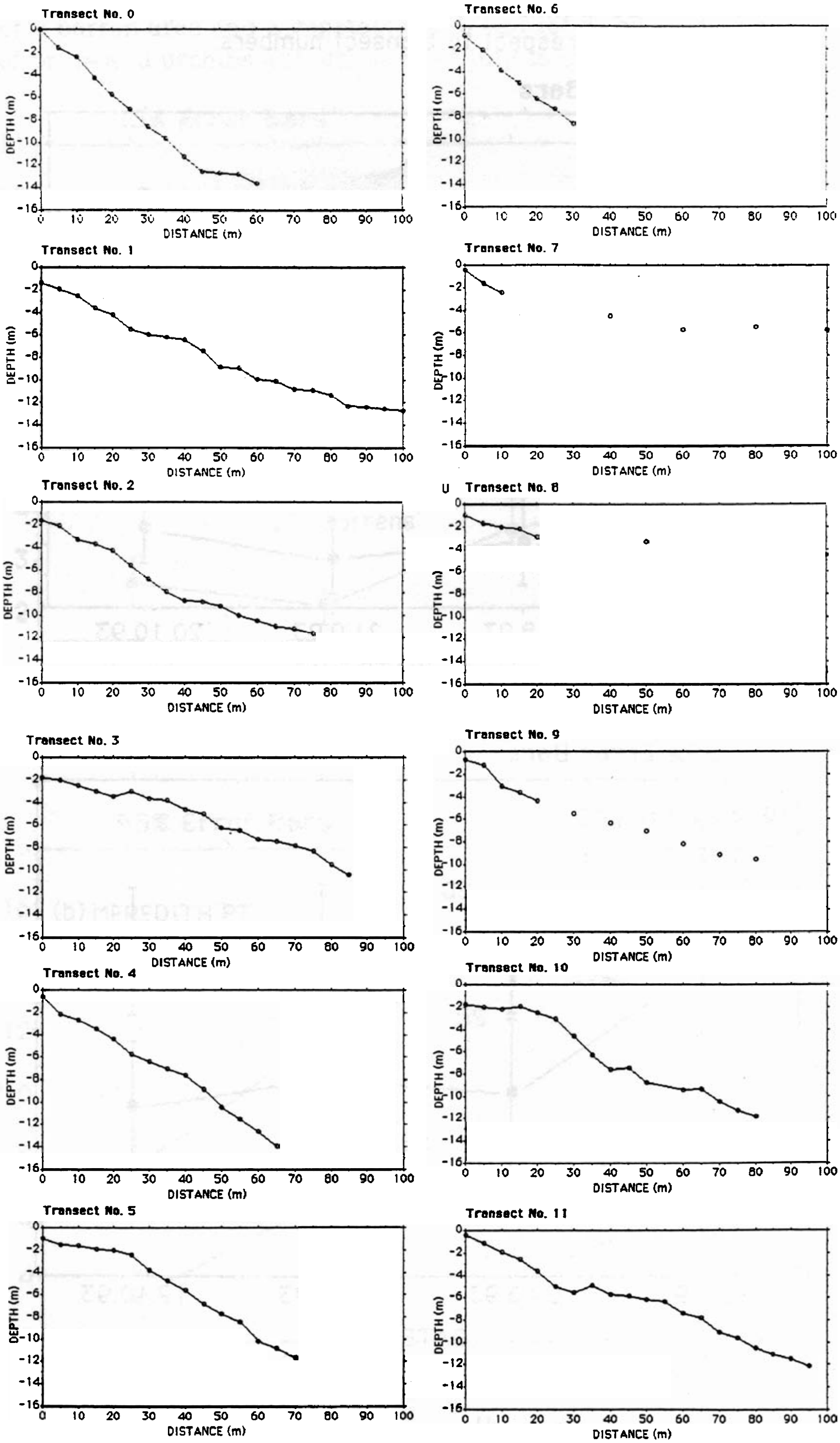


FIGURE 22 Graphs of substrate type versus distance for Hope Is.

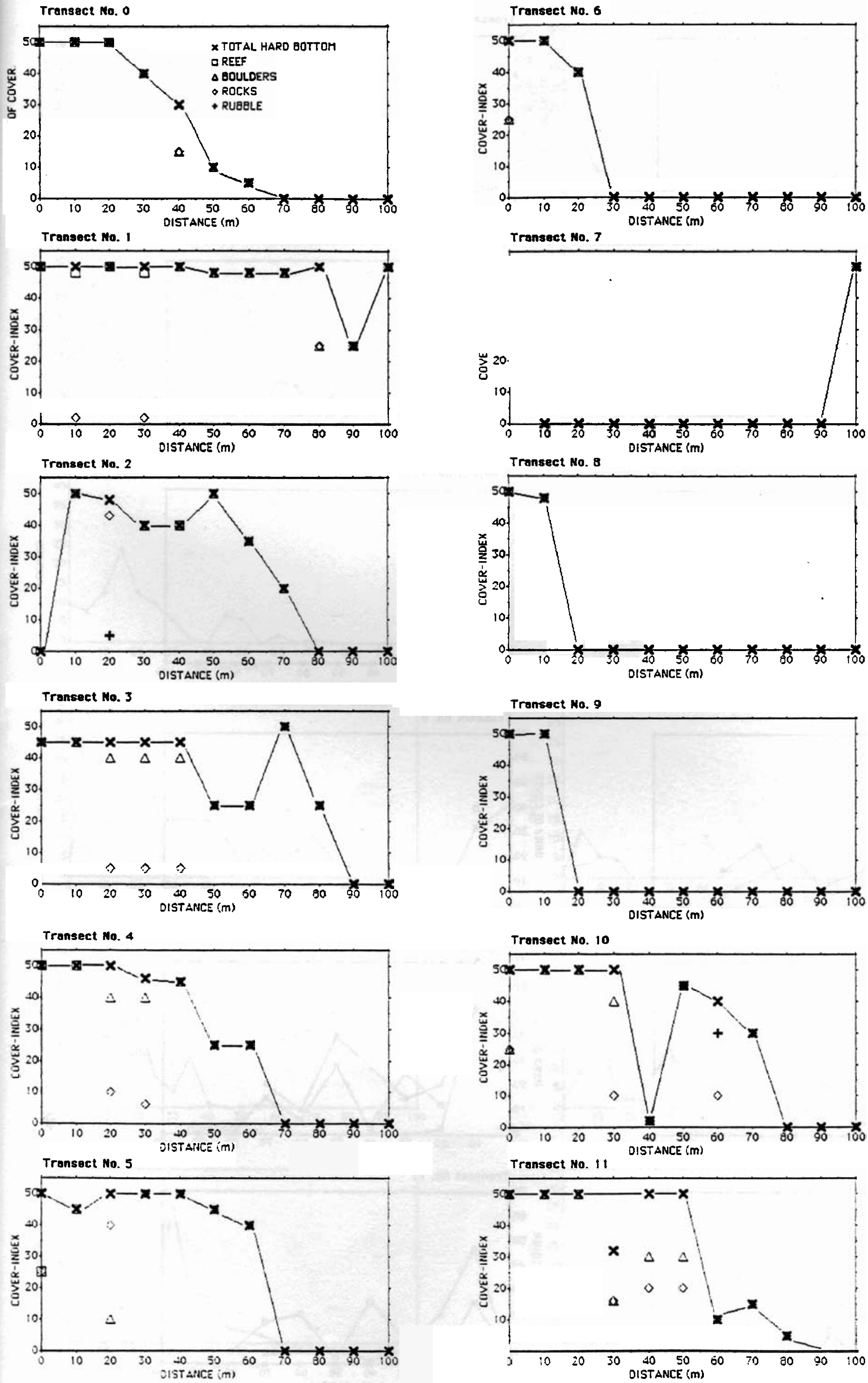


FIGURE 23 Graphs of algal cover versus distance for transects at Hope Island.

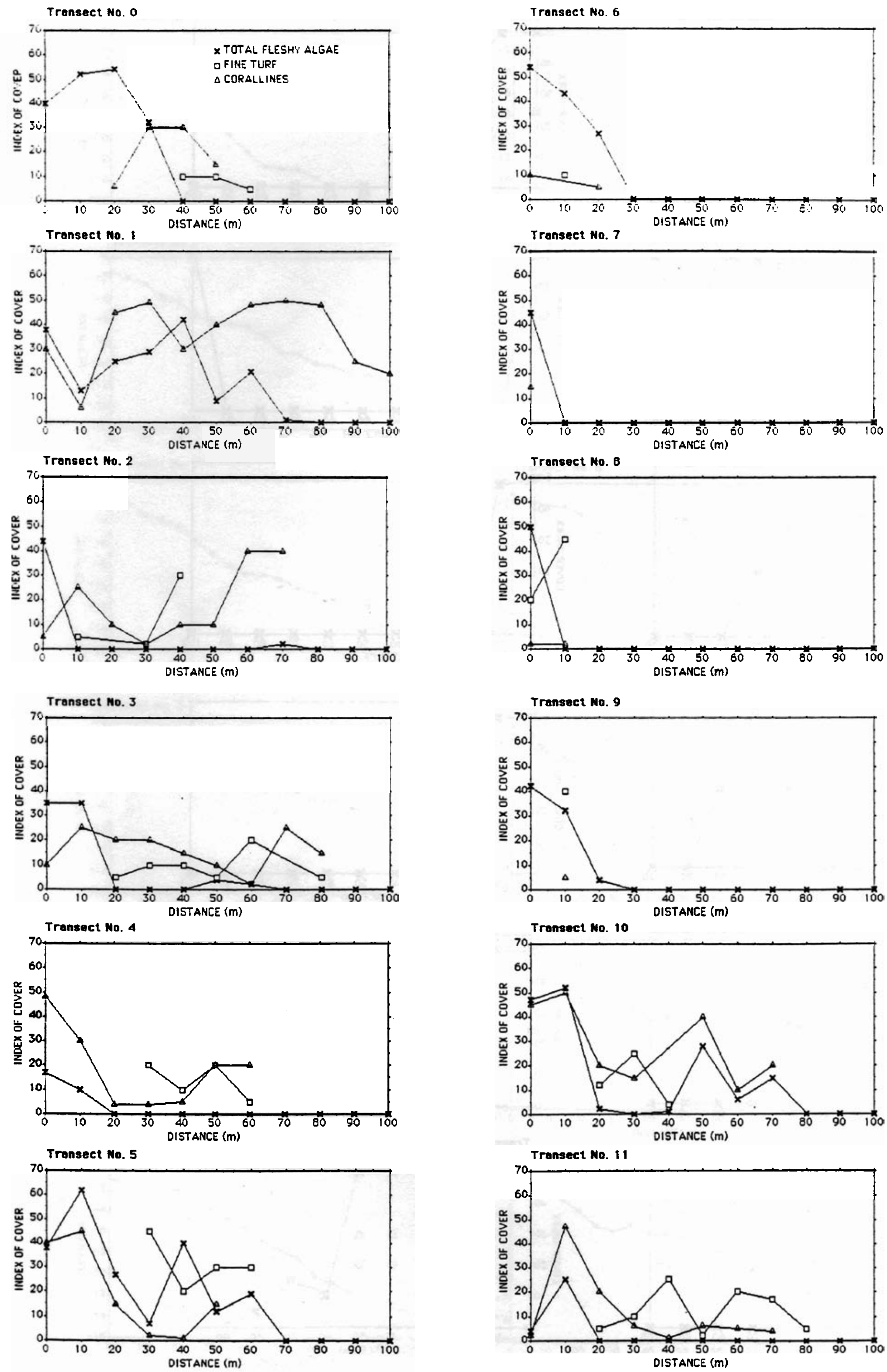
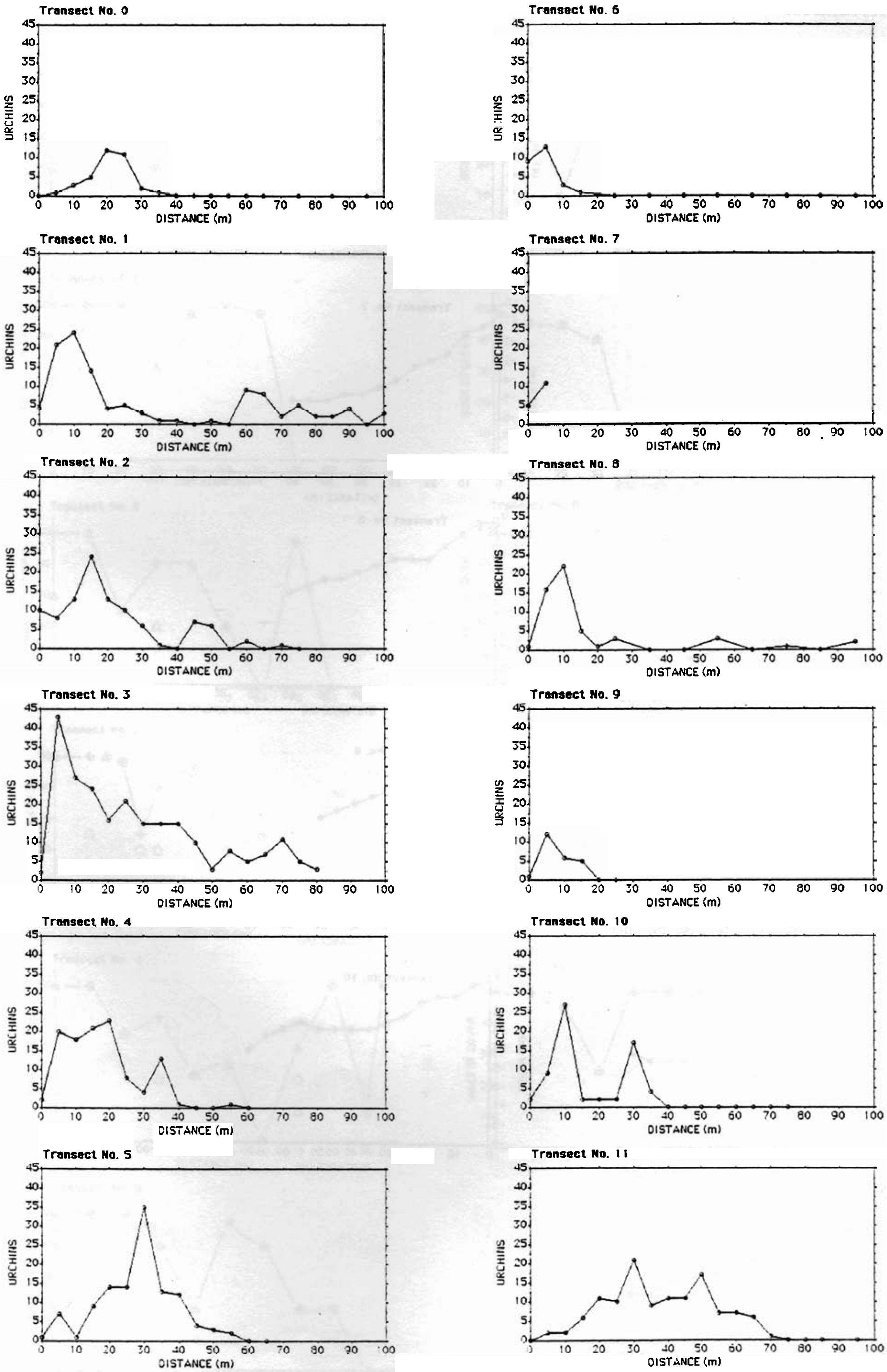


FIGURE 23Graphs of number of urchins in quadrats versus distance for transects at Hope Island.



DEPTH

FIGURE 25 Graphs of ~~number of urchins~~/quadrat versus distance for transects at Meredith Pt.

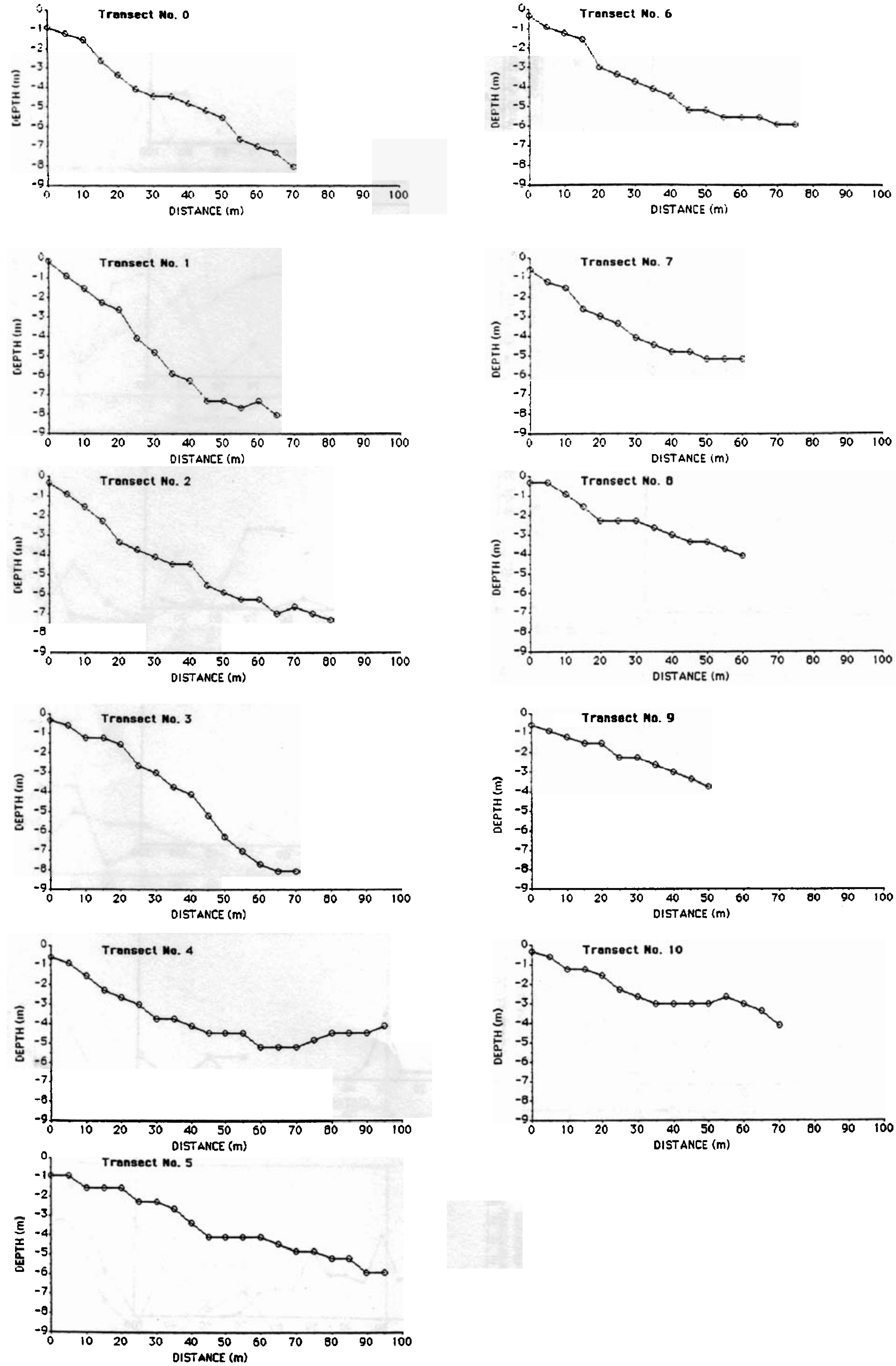


FIGURE 26 Graphs of substrate versus distance for transects at Meredith Pt.

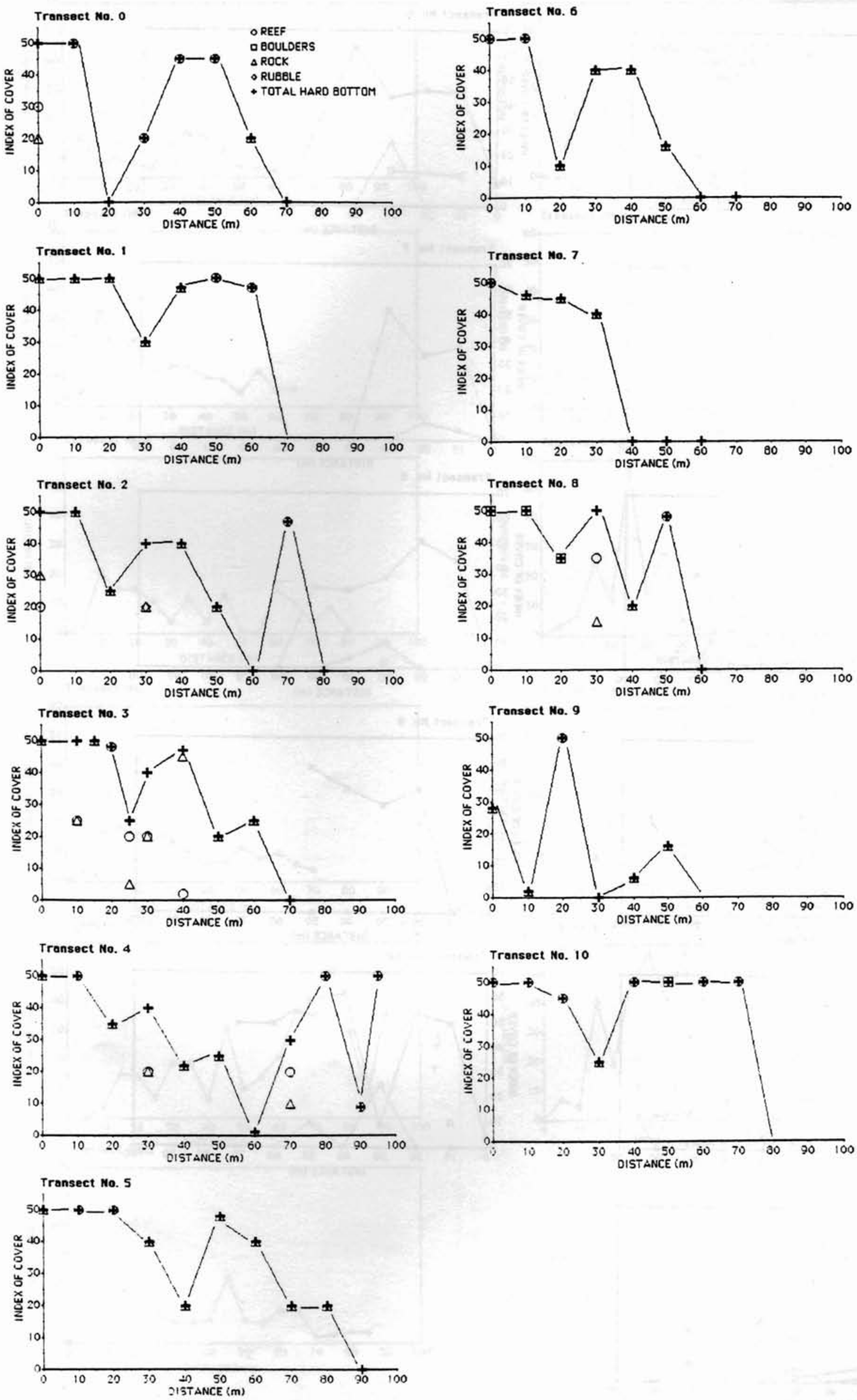


FIGURE 27 Graphs of algal cover versus distance for transects at Meredith Pt.

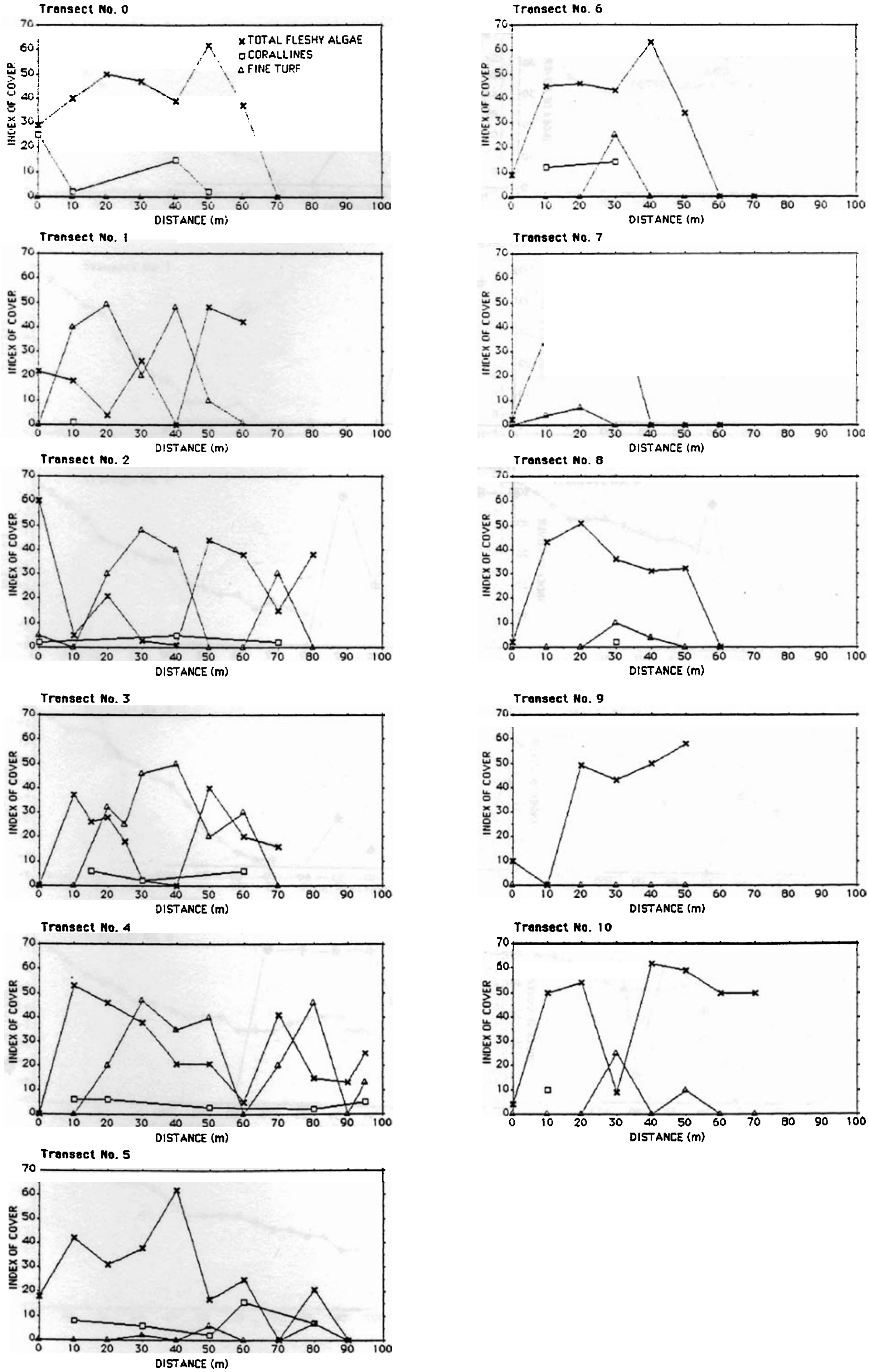


FIGURE 28 Graphs of number of urchin per quadrat versus distance for transects at Meredith Pt.

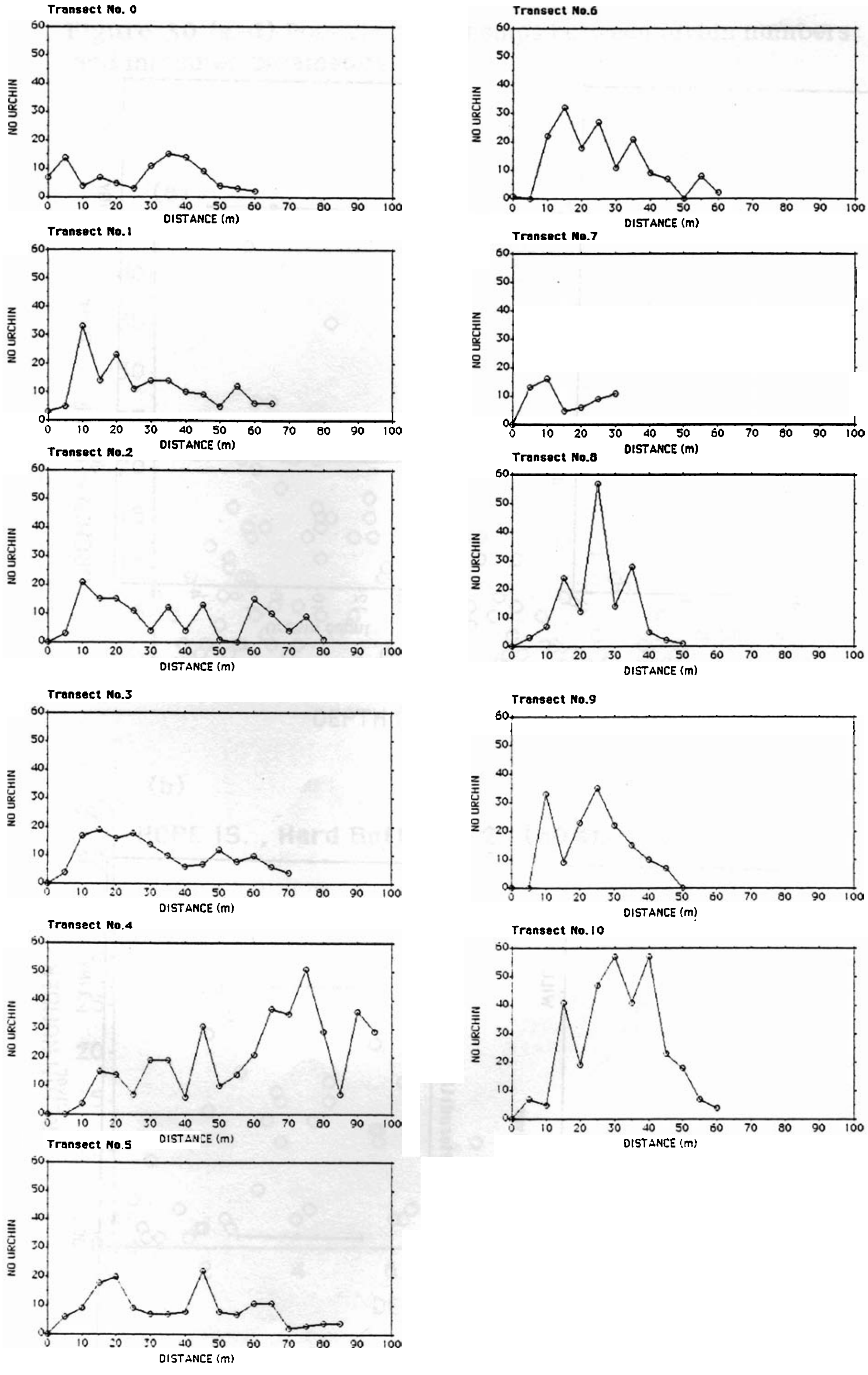


Figure 29 Comparison of diver counts on the same transects for adjacent, contiguous quadrats.

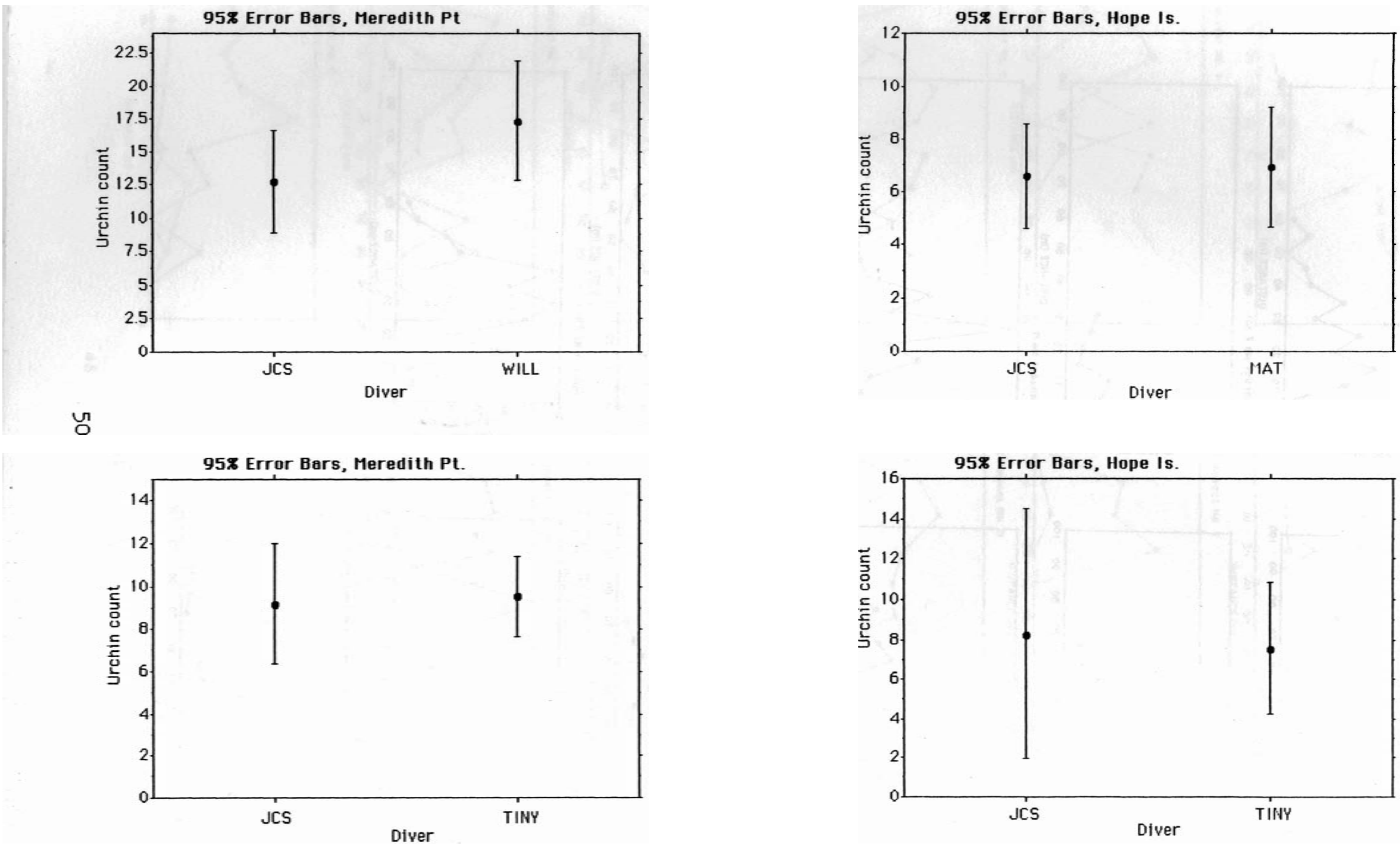
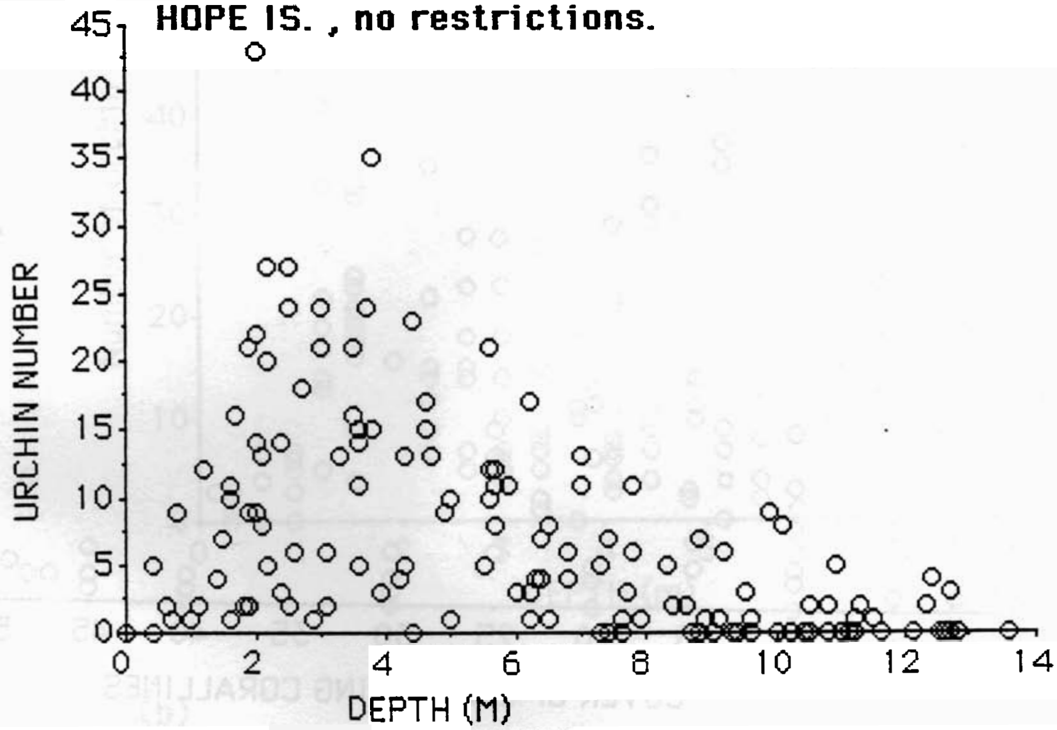


Figure 30 (a-d) Possible relationships between urchin numbers and measured parameters.

(a)



(b)

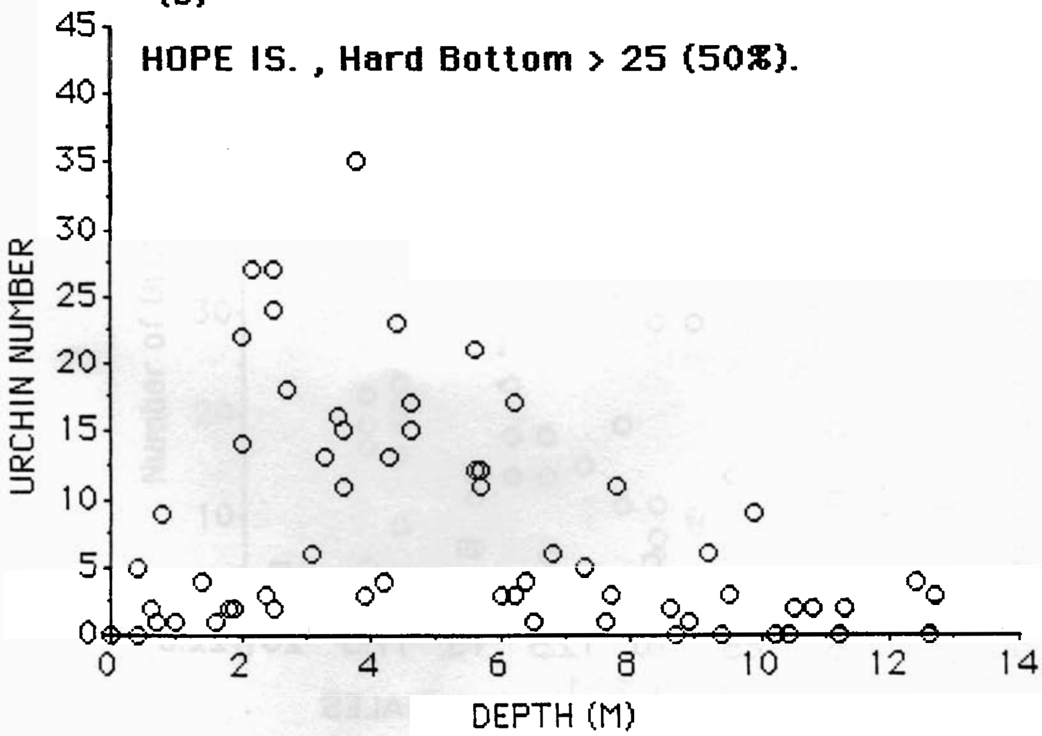
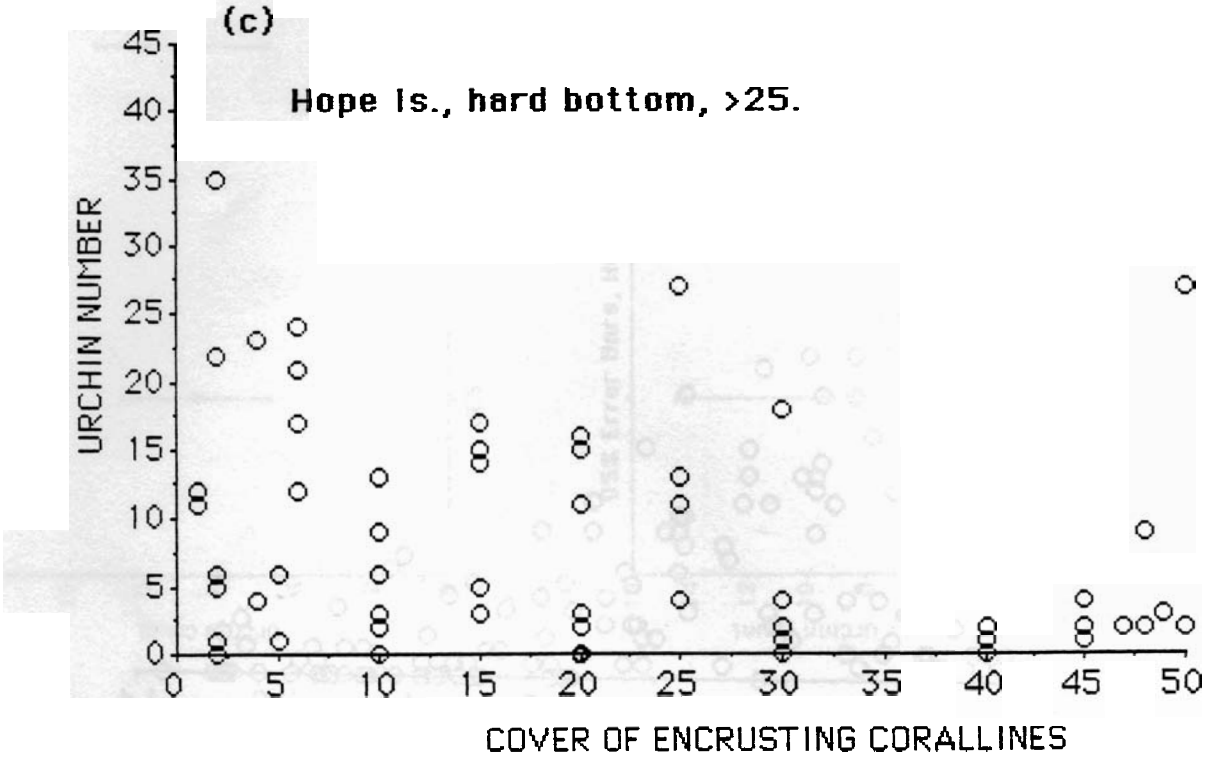


Figure 30 (a-d) Possible relationships between urchin numbers and measured parameters.



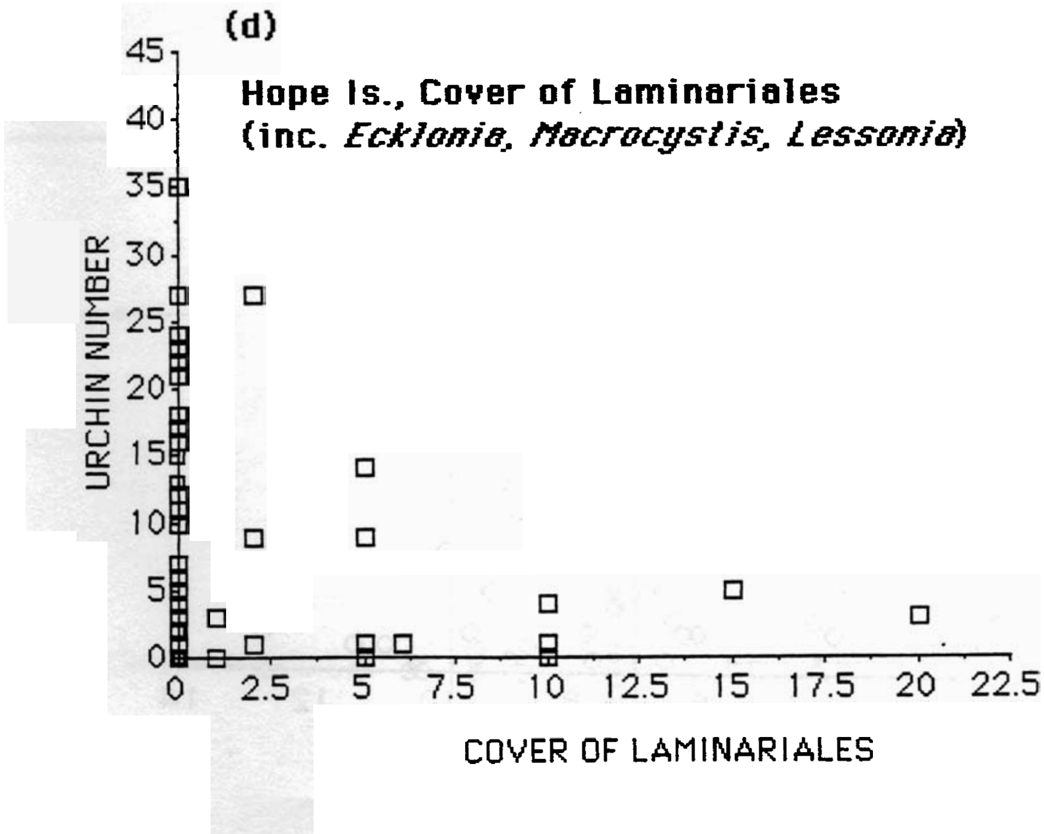
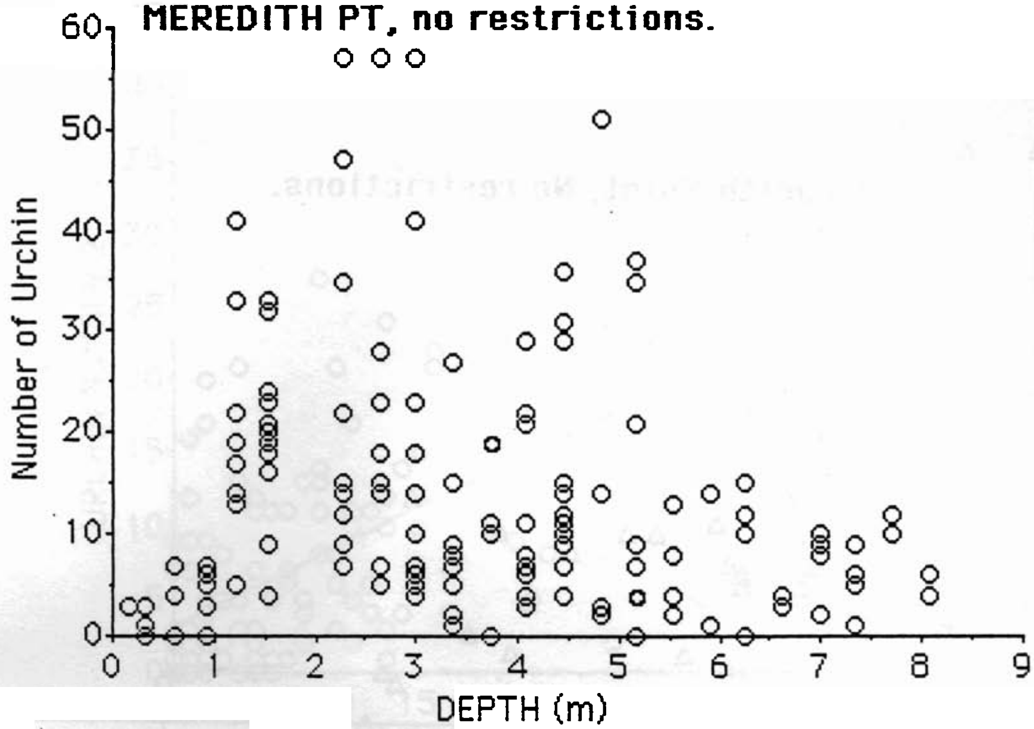


Figure 31 (a-d) Possible relationships between urchin numbers and measured parameters.

(a)



(b)

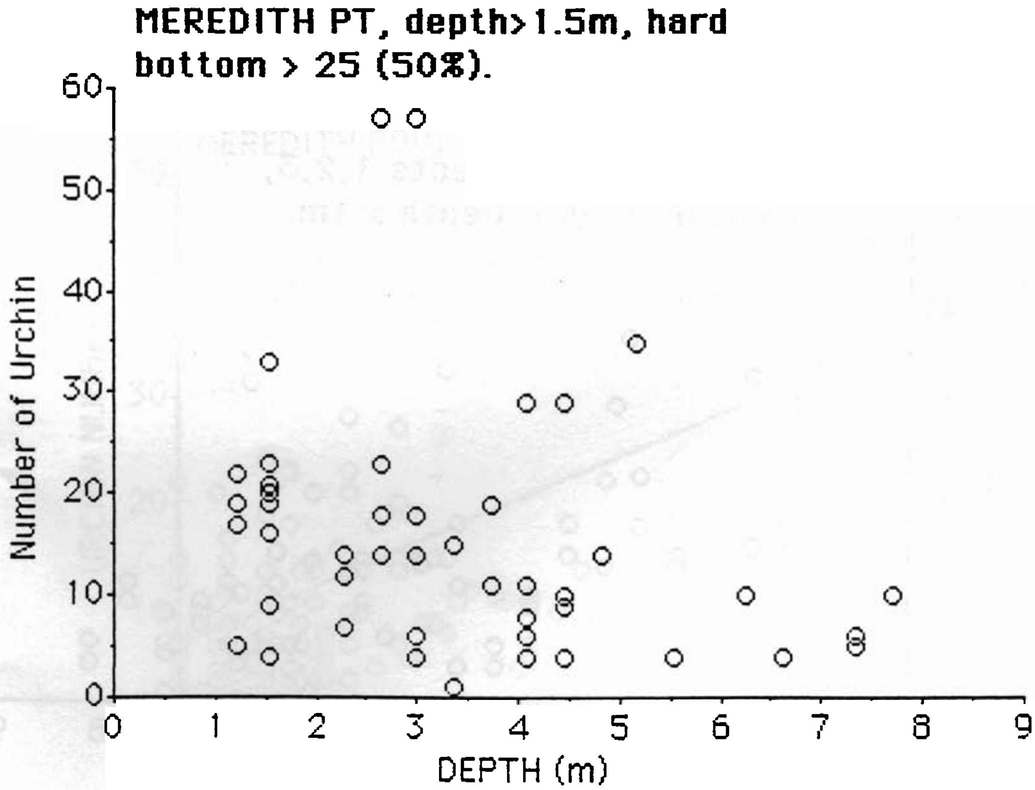
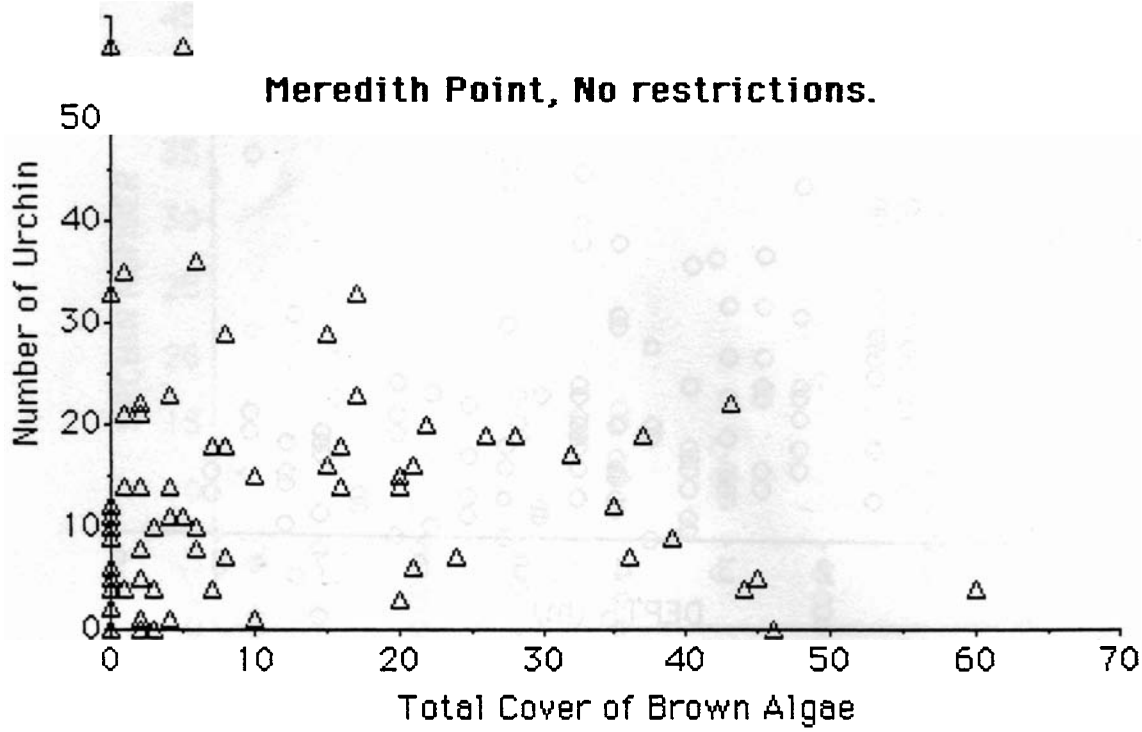


Figure 31 (a-d) Possible relationships between urchin numbers and measured parameters.

(c)



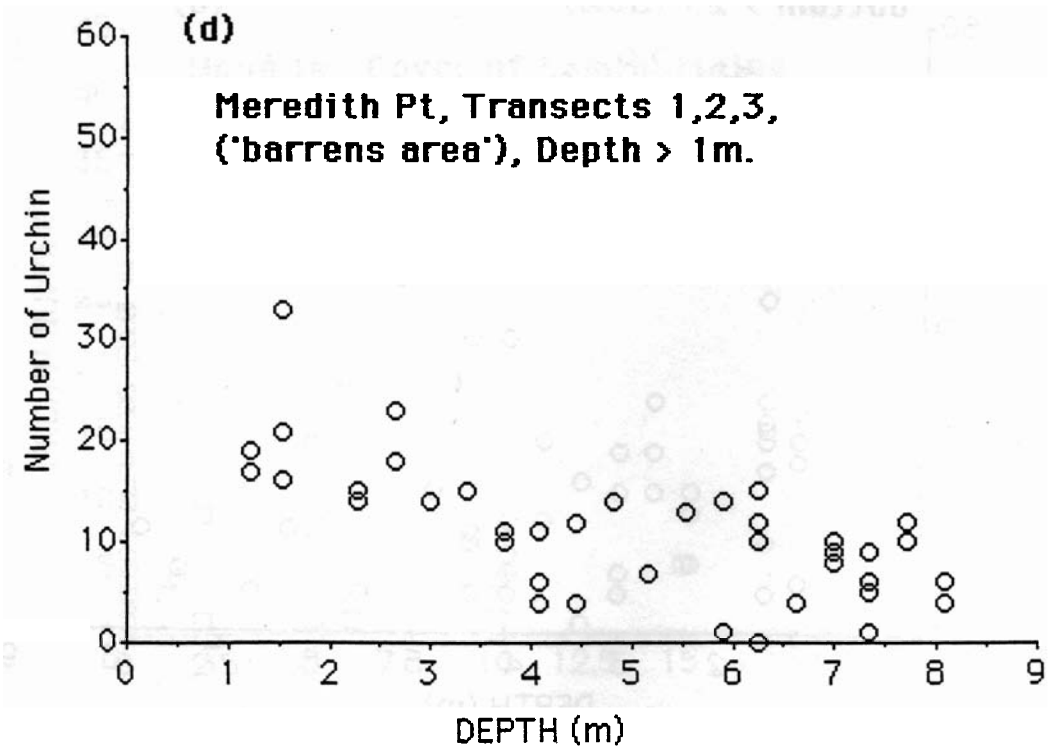
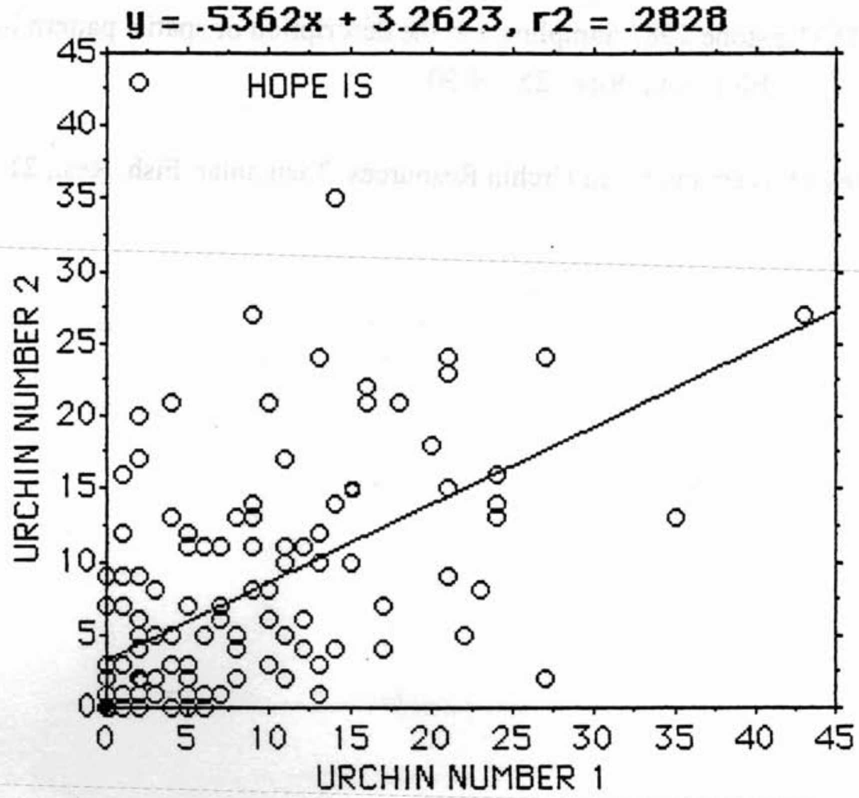
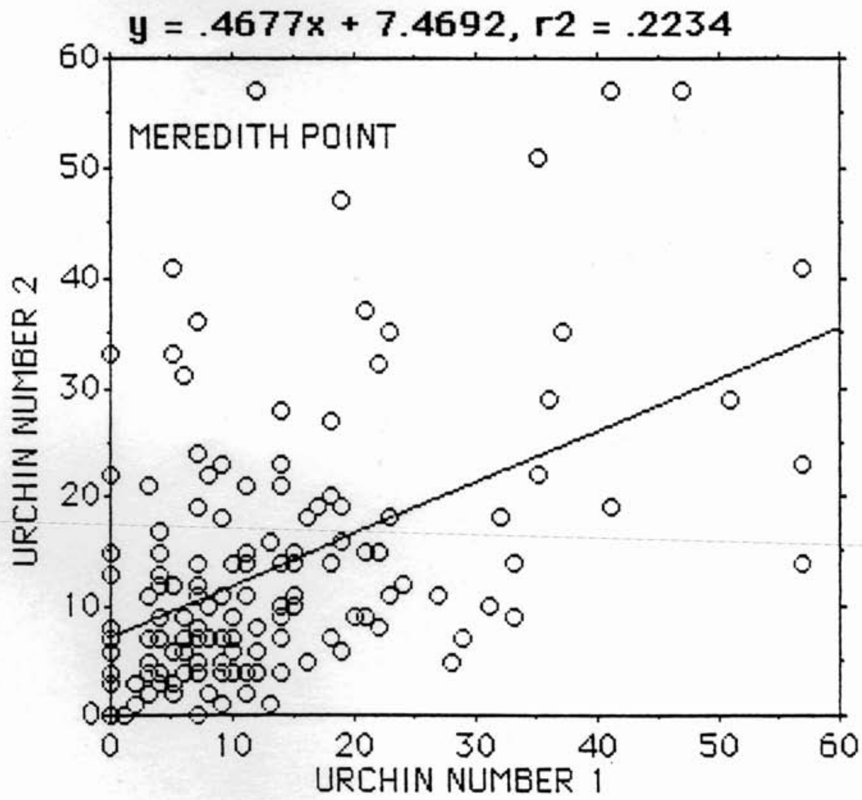


Figure 32

Check for autocorrelation between succesive quadrats for transect results at both sites.





REFERENCES

Andrew, NL and BD Mapstone 1987 Sampling and the description of spatial pattern in marine ecology. Oceanogr. Mar. Biol. Ann. Rev., 25: 39-90.

Dix, TG 1977 Survey of Tasmanian Sea Urchin Resources. Tasmanian Fish. Res., 21: 1-14.