

SHALLOW WATER CRINOIDS ARE ON SOFT SEDIMENTS TOO: EVIDENCE FROM A VIDEO SURVEY OF A SUBTROPICAL ESTUARY

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ABSTRACT

Remote underwater videography was used to map and characterize an unusual assemblage of epibenthic invertebrates on soft-sediments in subtropical Moreton Bay, Australia. The assemblage included congregations of the comatulid crinoid *Zygometa* cf. *Zygometa microdiscus* (Bell) at densities up to 0.88 individuals m⁻², comparable to those found in coral reef habitats. There was no correlation between the distribution of this species and commonly used abiotic surrogates depth (6–18 m), sediment composition, and residual current. The distribution may be related to patterns of tidal currents. There was also no relationship between the distribution of this crinoid species and other macrobenthic taxa, except a negative correlation with the occurrence of the sea pen *Virgularia gustaviana*. *Zygometa* is the only crinoid genus occurring commonly on local reefs that can swim, which may assist in locating suitable perches and reducing sediment load. It is not clear whether *Z. cf. microdiscus* is the same species as *Zygometa* sp. commonly occurring on local reefs, thus a habitat generalist, or a separate, soft substrate specialist species. This is the first quantitative assessment of crinoid density and distribution in shallow water, soft-sediment environments. The high densities found are significant in terms of the generally accepted picture of shallow-water crinoids as essentially reefal fauna. This highlights the conservation benefits of a more inclusive approach to marine habitat survey and mapping. Assemblages such as the one described, although they may be of scientific and ecological significance, would have been overlooked by common approaches to marine conservation planning, which emphasize highly productive, or aesthetically appealing habitats.

Continental shelf crinoid species (Phylum Echinodermata; Class Crinoidea) are not a noted component of soft substrate macrobenthos. They are obligate suspension feeders, long assumed to have a low tolerance to turbidity (e.g., Hyman, 1955). Moreover, since all extant shallow water species are unstalked (Order Comatulida) as adults, they must use their cirri, or in some cases adhesive pinnules, to attach themselves to a perch on the substrate and elevate their arms in one of several types of filtration fan array (Macurda and Meyer, 1983). For these reasons, shallow water crinoids are assumed to be characteristic of hard substrate, usually reefal environments (e.g., Fabricius, 1994).

The crinoid faunas of tropical and subtropical regions, where they have been described, are characterized by high species richness, but generally low abundance (Rutman and Fishelson, 1969; Macurda, 1973; Meyer, 1973; Zmarzly, 1984; Bradbury et al., 1987; Stevens, 1989; Fabricius, 1994). Assemblages with high density and low species richness have been described from polar and cool temperate waters (Marr, 1963; Könnecker and Keegan, 1973).

The developing field of remote underwater videography is allowing exploration of areas and community types not previously given priority. Remote videography allows cost-effective visual surveys without many of the logistical limitations of SCUBA or crewed submersibles (Holme, 1985; CSIRO, 1994). The recent emphasis on representation in marine conservation planning and management has given impetus to quantitative

surveys of areas not previously regarded as having high conservation or productivity values (Agardy, 1995).

This paper stems from a broader study to characterize and map marine benthic habitats at scales useful to managers. During the initial stages of that study, an unusual benthic assemblage from a subtropical estuary was noted: a surprisingly high density of comatulid (unstaked) crinoids occurring amongst an otherwise quite depauperate macrobenthic community. This paper presents descriptions and mapping of the assemblage using the low-cost remote videography techniques developed for the wider study. The significance of this assemblage is then discussed in ecological and marine conservation contexts.

Specifically, this study has two aims: to map the extent of a local soft-substrate crinoid population, and to characterize and map benthic assemblages in the study area.

METHODS

STUDY AREA.—The soft-sediment biota was surveyed within a 2.5×3 km area in Moreton Bay ($153^{\circ} 15' E$; $27^{\circ} 20' S$), Queensland, Australia (Fig. 1). Moreton Bay is a large (c. 1500 km^2), roughly triangular embayment opening to the Coral Sea towards the north. It is mostly shallow (< 20 m), although there are deep (40 m) channels in the north. It is protected on the eastern side by large sand islands. The bay receives significant freshwater and sediment inputs from the Brisbane River and several streams entering on its western shores year round, particularly during summer. Consequently, there is a strong gradient in mud and silt fraction in sediments from west to east (Lang et al., 1998) and a corresponding strong gradient in turbidity for much of the year (Dennison and Abal, 1999). The area sampled may, after heavy and sustained rainfall (principally in summer), experience lowered salinity (Dennison and Abal, 1999); however, significant rainfall did not occur during, or in the two weeks prior to sampling.

FIELD SAMPLING.—A digital video camera was used to obtain visual samples of macrobenthos in soft-sediment habitats in the study area. The SONY Digital-8 format camera was deployed in an IKELITE underwater housing. The camera was attached to a frame with the camera mounted at a fixed angle (45° down). The camera array was positively buoyant, and was kept a fixed distance above the bottom by a short length of chain attached to the frame, in a simplified version of the arrangement described in detail by Barker et al. (1999). The field of view of the camera is known (± 3 cm) and calibrated for several standard distances above the bottom. The video imagery analyzed for this paper was all taken with the camera lens suspended 30 cm from the substrate. This was necessary because visibility at this inshore site was rather low (surface Secchi depth < 3 m, visibility often < 1.5 m at the bottom). At this height, the field of view of the substrate is slightly over 50 cm wide at the nearest visible point to the camera, allowing a 0.25 m^2 frame to be superimposed on the video images to quantify density of benthic organisms.

The camera frame was attached by a 5 m tether to a 20 kg drop weight, which was suspended about 2 m above the substrate beneath the survey vessel. This arrangement minimized the positional uncertainty that would occur with a conventional long (unweighted) towline. In keeping with the low-cost aims of the overall project, the video array was small, lightweight and able to be easily deployed from a small craft.

In this study, 28 sites were sampled within a 3×2.5 km block, at a nominal spacing of 500 m (Fig. 1). Each site was represented by a single video transect of nominally 50 m. In fact, due to the time taken in deploying and recovering the unit, 100 m was allowed from deployment to recovery at the vessel, to ensure that at least 50 m was sampled on the bottom. With the camera at only 30 cm from the substrate, towing the unit even with the engine at idle resulted in blurred images, so a transect was effected by allowing the vessel to drift with wind and tide. Selection of sample sites was 'blind' in that the substrate was not visible from the surface, and there was no video feed to the

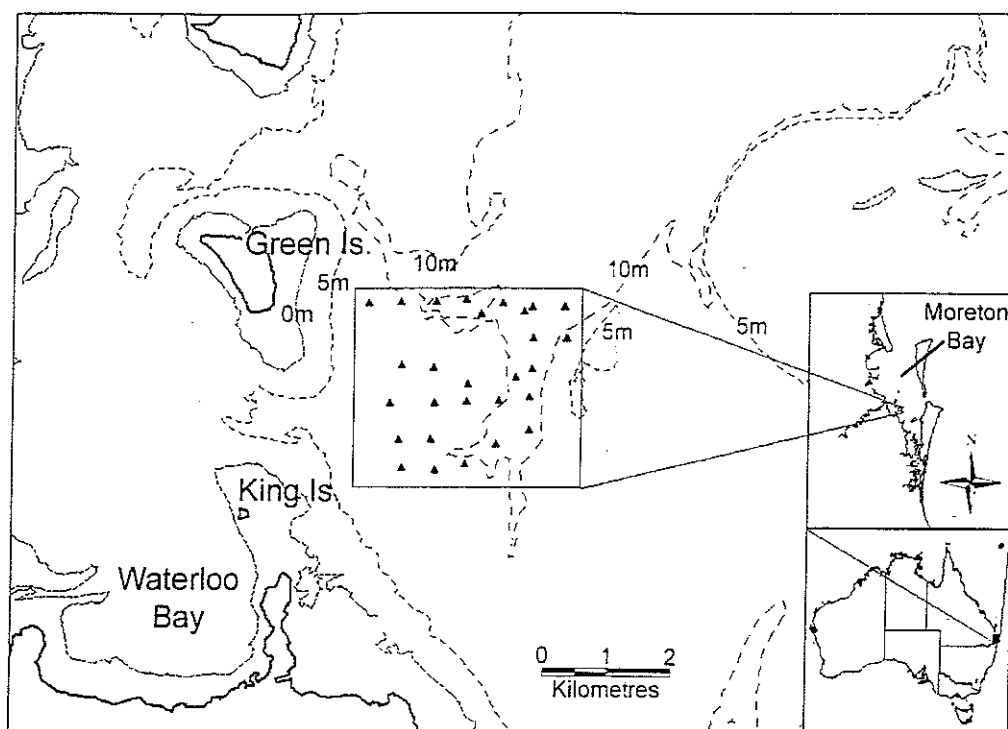


Figure 1. Map of the study area showing location of sampling sites. Depth contours are at 5 m intervals. (Redrawn from Moreton Bay Series Chart MB8. Queensland Department of Transport, 2000).

surface to influence selection of images. Sampling was conducted on four days between 14 February and 1 March 2001.

GPS was used to determine the position of the deploying vessel. Since the camera array was on a 5 m tether from a weighted drop line, which remained relatively vertical at all times, it was assumed to be within 10 m horizontally of the vessel at all times. This provides sufficient positional resolution for the scale at which mapping of marine habitats for conservation purposes is required (Stevens, 2002). Depth (± 0.5 m) was recorded at the beginning of each run and corrected for the state of the tide.

The video images were supplemented by two dives to collect reference specimens for identification. Identifications were verified with the Queensland Museum, and reference specimens deposited there (Voucher reference: QM G218354).

IMAGE PROCESSING AND DATA EXTRACTION.—Videotapes were first viewed on a large color monitor to identify organisms to the highest taxonomic resolution possible. Quantitative analysis was performed with digital images on a computer. The digital signal stream was captured at a nominal rate of one frame per second and saved as a digital movie file. The movie file was post-processed using digital filters to enhance image clarity and contrast, which greatly aids recognition of benthic organisms. Further processing was undertaken to add time code and frame number data. A mask was overlaid to delineate a known sample area of 0.25 m^2 .

Data extraction was carried out by viewing each movie frame by frame. Counts of solitary and discrete colonial organisms (ascidians and sea whips) were scored by recording the number within the mask overlaid on each frame. These were then summed for the entire run, and converted to densities for analysis. Formal decision rules were erected to determine the usefulness of each frame. Frames were discarded if the image was blurred, partially or completely obscured, out of correct orientation (camera tilted or at the incorrect distance from the bottom), a partial or complete overlap of a preceding image, insufficiently lit, or overexposed. The number of frames per run varied from 64–246 with a mean of 114.

For the purpose of these analyses, a whole transect (rather than individual frames) was considered a single sample. Other work (Stevens, unpubl. data) has shown that one run is sufficient to characterize a 50 m swath, provided that frame spacing is optimized to maximize coverage without overlap.

ANALYSIS.—Density values were plotted on spatial co-ordinates representing the mid-point of each transect, to produce raw distribution plots of crinoids and other taxa. The distribution of crinoids was examined for possible relationships with abiotic parameters depth, mud and sand fraction in sediments, and residual current velocities (background water movement after removal of tidal effects – derived from summing tidal velocity vectors over the entire cycle) obtained from Dennison and Abal (1999). Relationships were tested using regression analysis for depth and by visual comparison of maps for the other parameters since numeric data at the scale of this study was not available.

Densities of crinoids and other taxa were compared using correlation analyses to test for relationships of co-occurrence or spatial separation. Non-parametric (Spearman's Rank) analysis was necessary because preliminary testing showed that data distributions for all taxa were non-normal.

Multivariate techniques were used to look for patterns of relative homogeneity in community structure within the study site. The sites by taxa matrix was $\log(x + 1)$ transformed to limit the influence of the few very high density sites/species. A combination of K-means divisive clustering and more conventional agglomerative clustering (unweighted pair group method with arithmetic means) was used and the results compared to ordinations derived from multi-dimensional scaling. The Bray-Curtis similarity measure was used because it ignores conjoint absences, particularly important in this depauperate dataset (Clarke and Warwick, 1994).

Memberships of groups derived from multivariate analyses were plotted on real spatial co-ordinates of sampling sites, and notional community boundaries derived from a smoothed 250 m buffer around sampling points.

RESULTS

GENERAL CHARACTERISTICS OF THE STUDY AREA.—Depth in the sampled area varies from 6–18 m (Fig. 1), in a general gradient from west to east. Sediments were assessed visually as ranging from mud and shell grit in the northwest to sandy mud with less shell grit in the southwest, with an increasing proportion of sand, and loss of shell grit, toward the eastern side of the sampled area. This agrees in broad terms with the mapping from Dennison and Abal (1999), although their map is interpolated from relatively widely spaced data points.

In terms of the sedimentary environments of Moreton Bay, the study area lies within a zone of minimal deposition, but clearly represents a gradient of influences from an in-shore prodelta mud and silt depositional zone to the west (Waterloo Bay), and the marine tidal delta sand zone to the east (Amity Banks; Lang et al., 1998).

SPECIES DISTRIBUTIONS.—The survey revealed a depauperate epibenthic community. Densities of only eight macrobenthic taxa were quantified from the video data (Table 1). Of these, two occurred as single individuals in only a few sites. Of the 168 cells in the remaining six taxa by 28 sites matrix, 66 (39%) were zero values. Seagrass and macroalgal cover was not quantified, because it almost never occurred, although evidence of rhizome mats was visible in sites in the southwest corner of the study area. Occasional patches of sparse seagrass *Halophila ovalis* were noted in several of the deeper sites, but did not appear within the sampling mask.

The most unusual feature of the dataset is the presence at relatively high densities of a single species of the comatulid crinoid genus *Zygometra*. This species was identified from the keys in Clark and Rowe (1971), the most recent treatment of this family. How-

Table 1. Abundance of benthic macrofauna over 28 sites within the study area. Mean density over all sites, maximum site density, and frequency of occurrence as a percentage of all sites. Density units are individuals m^{-2} .

Species	Type	Mean density	Maximum density	% frequency
<i>Polycarpa papillata</i>	Solitary ascidian	0.366	1.143	100
<i>Eudistoma elongatum</i>	Colonial ascidian	0.174	1.116	79
<i>Zygometa</i> cf. <i>microdiscus</i>	Crinoid	0.114	0.883	64
<i>Guaiaigorgia</i> sp.	Seawhip	0.096	0.696	64
<i>Sphenopus marsupialis</i>	Zooanthid	0.074	0.329	64
<i>Virgularia gustaviana</i>	Short Quill Sea Pen	0.033	0.235	29
<i>Holothuria</i> sp.	Holothurian	0.008	0.071	14
<i>Cerianthus</i> sp.	Anemone	0.003	0.076	7

ever, the taxonomy of the Zygometridae is unclear, with Clark and Rowe (1971) noting that some of the species of *Zygometa* in the Indo-West Pacific are probably untenable (*ibid* p. 17). Specimens from the study site were compared to those of the genus *Zygometa* held by the Queensland Museum. Whilst there is a lot of variability within the specimens held in the Museum, those from this study are more like *Z. cf. microdiscus* than any other species in the genus. The Queensland Museum (Davie et al., 1998) lists the form occurring on local reefs as *Zygometa* sp. and states that it may be a new species (*ibid* p. 221). Given this uncertainty, for the purposes of this paper the species is referred to as *Zygometa* cf. *Z. cf. microdiscus* (abbreviated as *Z. cf. microdiscus*), acknowledging that the taxonomy of the genus *Zygometa* is in need of review.

Crinoids occurred over most of the study area (Fig. 2). Higher densities were found on the central western side of the study area. The highest density of crinoids occurred in site 5, where there were 0.88 individuals m^{-2} . Mean crinoid density over all 28 sites was 0.11 individuals m^{-2} (SD = 0.18 individuals m^{-2}). *Zygometa* cf. *microdiscus* occurred in 64% (18 of 28) of sites. The maximum density recorded in any single frame was 20 individuals m^{-2} (the highest for any taxon). All individuals were within the range of approximately 150–200 mm across and were therefore considered adults (Davie et al., 1998). No juvenile specimens were observed.

The most abundant species over the entire study area was the solitary ascidian *Polycarpa papillata* (Table 1). Mean density was 0.37 individuals m^{-2} (SD = 0.29 individuals m^{-2}), with a maximum of 0.92 individuals m^{-2} in site 5. This species was also the most widespread, occurring in all sites.

Other taxa that occurred regularly (in more than half of the sites) were the colonial ascidian *Eudistoma elongatum*, a seawhip of the family Gorgonidae, probably *Guaiaigorgia* sp., and the zooanthid *Sphenopus marsupialis*.

ASSEMBLAGES.—The two clustering methods gave identical results at the four group solution, and this was found to agree well with the relationships apparent in the MDS ordination plot (Fig. 3). Stress level in the MDS (0.18) was acceptably low for two dimensions, given the agreement with the clustering results (Clarke and Warwick, 1994). The derived group membership, when plotted onto the real spatial co-ordinates of the sites, results in the community map (Fig. 4). Comparing the groups with the original data matrix showed that group 1 consisted of a single site containing very high densities of both crinoids and solitary ascidians. Group 2 contained four sites in the southwest corner of the study area characterized by moderate to high densities of solitary ascidians and

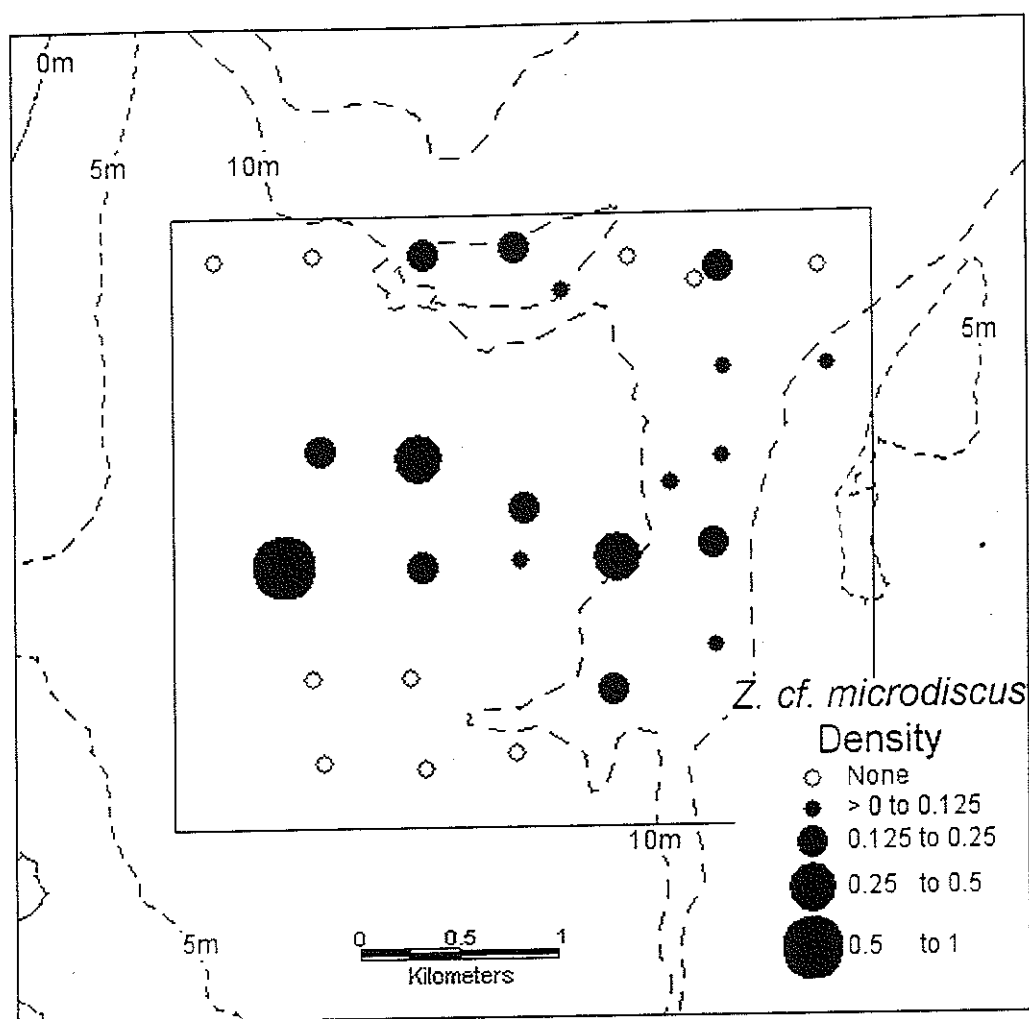


Figure 2. *Zygometra cf. microdiscus* densities at the 28 sampling sites. Units are individuals m^{-2} .

colonial ascidians, with no crinoids present. Group 3 was a large group of undifferentiated sites occupying the bulk of the study area, characterized by a mix of most taxa. Group 4 also contained a single site, characterized by a very high density of seawhips. It is evident from comparison of Figures 2 and 4 that the community composition derived from the multivariate analyses is not driven strongly by crinoid density, except in the case of the very high density of crinoids at the site that formed group 1.

Correlation analyses showed no significant relationships between distributions of crinoids and any other taxon, either positively (co-occurrence) or negatively (spatial separation). The only exception to this was a significant negative relationship between crinoid and sea pen (*Virgularia gustaviana*) densities ($r = -0.332$, $P = 0.042$), indicating that these two taxa are spatially separated. Examination of the data matrix showed that while *Z. cf. microdiscus* occurred in 18 of the 28 sites, and *V. gustaviana* in eight, the two taxa co-occurred in only three sites.

RELATIONSHIPS WITH ABIOTIC SURROGATES.—The relationship between depth and crinoid density was not significant ($P = 0.15$) and the R^2 value was very low (0.08) indicating that depth was not an important determinant of crinoid distribution. This is not surprising, as the depth range of 6–18 m is unlikely to be limiting for crinoids (Stevens 1989). The

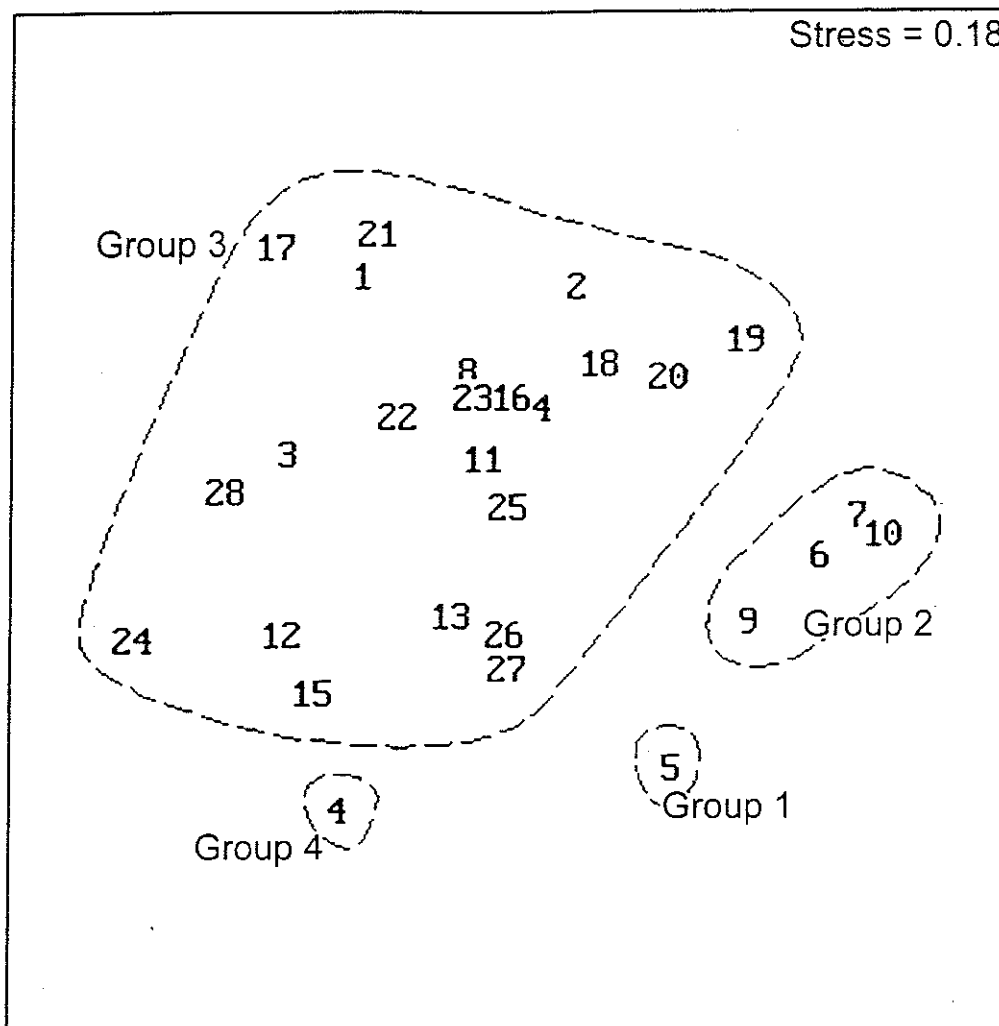


Figure 3. MDS ordination plot of taxon density data showing four groups derived from multivariate analysis.

maps of mud and sand fraction in sediments, and residual current velocities in Dennison and Abal (1999) were derived from interpolation between relatively (compared to the distance between the sites in this study) widely spaced data points, hence no numerical analysis was attempted. From visual examination, there appeared to be no relationship between the distribution of these abiotic factors and crinoid distribution.

DISCUSSION

CRINOID DENSITIES WORLDWIDE.—There have been few quantitative surveys of shallow-water crinoid abundance and species richness worldwide (Table 2), and all have been undertaken on tropical or subtropical coral reefs in Jamaica (Meyer, 1973), Enewetak Atoll (Zmarzly, 1984), Davies Reef (Bradbury, et al., 1987) and other reefs of the central Great Barrier Reef (Fabricius, 1994), and Heron Island and Wistari Reefs (Stevens, 1989). The only record of comatulid (unstalked) crinoid density estimates on soft-sediment sub-

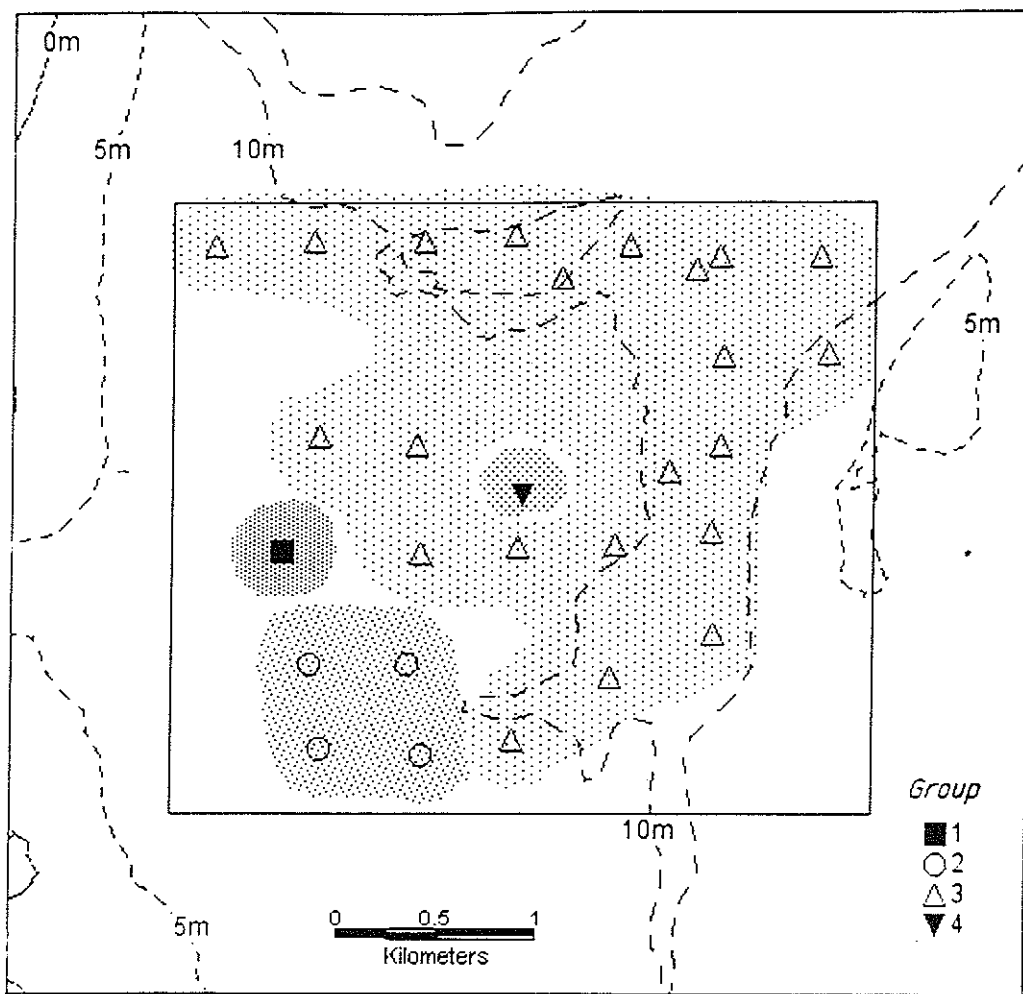


Figure 4. Community map derived from groups selected using multivariate analysis. Notional group boundaries are based on a 250 m buffer around sampling points, since nominal site spacing was 500 m.

strates is from dredged and trawled samples from deep to abyssal (75–4862 m) waters on the Antarctic Shelf (Marr, 1963).

The most extensive quantitative survey of crinoid abundance and species richness was undertaken by Stevens (1989), who surveyed almost 10,000 m² in transects on Heron Island and Wistari Reefs at the southern end of the Great Barrier Reef. The current study surveyed about 750 m², and while not at the same scale, found maximal and mean densities of a single species at the same order of magnitude as the combined mean or single-transect maximum of all 36 species in Stevens' (1989) study. Densities at similar orders of magnitude are reported in other studies of shallow water crinoids (Table 2). It should be noted that the other studies were carried out in areas found by preliminary surveys to be those with high crinoid densities (Meyer, 1973; Zmarzly, 1984), or with the deliberate intention of characterizing reef zones on the basis of crinoid fauna (Bradbury et al., 1987; Fabricius, 1994). The very high densities found in the study by Fabricius (1994) were partly as a result of the deliberate placement of 1 m² quadrats to sample crinoids, and because the coral substrate beneath quadrats was excavated to extract cryptic species.

Table 2. Comparison of quantitative studies on shallow water crinoid species richness and density worldwide. Density units are individuals m^{-2} .

Location	Species richness	Mean density	Maximum density	Source
Moreton Bay, Australia	1	0.110	0.88	Present Study
Heron Island and Wistari Reefs (southern Great Barrier Reef), Australia	36	0.108	1.81	Stevens, 1989
Central Great Barrier Reef, Australia	43	7.1	70	Fabricius, 1994 ¹
Davies Reef (central Great Barrier Reef), Australia	27	0.470	1.02	Bradbury et al. 1987
Enewetak Atoll, Marshall Islands	6	0.071	0.142	Zmarzly, 1984 ²
Discovery Bay, Jamaica	4	0.220	0.220	Meyer, 1973 ³

⁽¹⁾ This study was based on 1 m^2 transects placed to characterise reef zones on the basis of crinoid fauna, and involved excavation of the substrate to a depth of 70 cm to extract cryptic species. ⁽²⁾ Overall density value given in Zmarzly (1984) is "within a zone of peak abundance approximately two times the overall densities." (ibid page 112), so it is treated here as the maximum, with mean density calculated as half that value. ⁽³⁾ Maximum values not given, but "The population censused probably represents the maximum size for crinoid populations in this vicinity" (Meyer 1973, pages 244–245) so mean and maximum values are the same.

Harrison et al. (1998) recorded densities of reef benthos at two sites close to the study area: Myora Reef within Moreton Bay (about 13 km from the study area), and Flinders Reef in the open sea north east of Moreton Bay (about 52 km from the study area). The data presented included total numbers of crinoids, although the number and identity of species is not given. No crinoids were recorded from Myora Reef, and densities at Flinders Reef varied from 0.1–1.0 individuals m^{-2} , similar to those found in this study.

In terms of single species densities, *Z. cf. microdiscus* in this study occurred at higher densities than the bulk of species in previous reef-based surveys. For example, only nine of the 43 species recorded by Fabricius (1994) at central Great Barrier Reef sites occurred at higher mean densities, even given the bias towards high densities in that study. No single species in Stevens' (1989) study occurred at higher mean densities.

The occurrence of *Z. cf. microdiscus* in the turbid, soft sediment location of the present study at high densities, comparable to individual species, or total crinoid densities, found in coral reef surveys is significant in terms of the generally accepted picture of crinoid ecology. Congregations of comatulid crinoids in soft-sediment, relatively turbid, environments have not been previously described in subtropical and/or estuarine waters, although they occur at very low densities in inter-reefal regions of the Great Barrier Reef (Birtles and Arnold, 1989). An exception to this is an anecdotal account of an assemblage of the same species (*Z. cf. microdiscus*) on soft substrate in Bowling Green Bay, a marine embayment near Townsville, Australia (D.L. Meyer, Univ. of Cincinnati, pers. comm.). That account supports the contention of this paper that crinoids can no longer be regarded as essentially reefal fauna.

INFLUENCES ON CRINOID DISTRIBUTION.—Comatulid crinoids as adults lack the stalk and holdfast retained by their deep-water relatives, and require a perch to which they cling using their cirri, or in some species (Family Comasteridae) adhesive pinnules (Macurda and Meyer, 1983). They are relatively unselective (although some specialist species have clear perch preferences) and are frequently epizoic (Stevens 1989).

In a soft substrate environment, a firm perch is still required, and might be expected to be a limiting factor. In this study, *Z. cf. microdiscus* was found clinging to a variety of perches including mollusc shells (living, whole dead or larger fragments), isolated dead

coral clumps, solitary ascidians, zooanthids, and artificial objects (bottles and cans). However, there is no evidence that perch availability was a limiting factor in the distribution of *Z. cf. microdiscus*, since in the majority of sites there were many more available perches (both biotic and abiotic) than crinoids. No correlation was observed between the densities of solitary ascidians or zooanthids and that of *Z. cf. microdiscus*. Interestingly, seaweeds were never observed to be used as perches, whereas in reefal environments they are commonly used, albeit by a group of specialist crinoid species not occurring here (Stevens 1989).

Crinoids are described as moderately to strongly rheophilic (Meyer, 1982), since they are passive filter feeders. Reversing tidal velocities (as distinct from residual current velocities) were noted to be highest in the central western sites, closest to the channel between King and Green Islands, where the water mass must pass through a relatively constricted opening to enter and leave Waterloo Bay. This corresponds in broad terms with the sites of highest crinoid density and may explain the preference of *Z. cf. microdiscus* for these sites. However, it does not explain how crinoids are able to occur in such an environment at all.

A partial explanation for the occurrence of *Z. cf. microdiscus* in the study area may be the ability of this crinoid species, in common with many in this and other non-comasterid families, to swim by undulating alternate arms, and indeed, it was observed doing so. The swimming is not powerful, but enables the animal to elevate itself above the substrate, facilitating transport by currents as described by Shaw and Fontaine (1990). Other (non-swimming) crinoids must search for appropriate perches by crawling over the substrate, which may be problematic in a soft-sediment environment. While not tested in this study, it is postulated that swimming activity may also enhance survival on soft substrates by removing sediment buildup from the filtering pinnules and ambulacral groove.

There are five species of crinoid commonly occurring on local reefs including *Zygometa* sp. (Davie et al., 1998), although up to 13 species have been recorded (Stevens, unpubl. data). Of these common species, only *Zygometa* sp. is capable of swimming. Given the uncertainty of the taxonomy of the Zygometridae, it is not clear whether this is the same species as *Z. cf. microdiscus*. Until the taxonomy is resolved, it is not possible to say whether *Z. cf. microdiscus* occurs on soft substrates in Moreton Bay because it is the only one of the locally available pool of crinoid species able to survive in these conditions, or because it is a soft substrate specialist.

SIGNIFICANCE OF THE ASSEMBLAGE.—It is not possible to say whether this crinoid population is widespread within the Moreton Bay region, or whether this type of soft sediment assemblage is found in other subtropical estuaries, although the account of D.L. Meyer (Department of Geology, University of Cincinnati, pers. comm.) suggests it may be. Therefore, it is difficult to assign a conservation or representational significance to it. This would also require some assessment of threat, and the temporal persistence of the assemblage. However, Moreton Bay is the site of the major port of Brisbane, and several marine research stations. The Bay has been quite extensively studied from the perspective of fisheries productivity and benthic ecology (see summaries in Crimp, 1992; Tibbetts et al., 1998). Therefore, it is surprising that this crinoid population has not been previously described. Crinoids do not appear in species lists from the extensive benthic sampling carried out in Moreton Bay during the 1970s and 80s (Poiner, 1977; Stevenson and Cook, 1977; Stevenson et al., 1978; Young and Wadley, 1979; Stevenson, 1980; Poiner and Kennedy, 1984). Therefore, it may be that the densities described in this report are a

localized or recent phenomenon, or that more conventional survey methods (dredge, grab, trawl) under-represent crinoid populations.

The unusual assemblage described in this study also highlights the conservation benefits of a more inclusive approach to marine habitat survey and mapping. An inclusive approach here means one which surveys, and aims to represent, all available habitat types at scales relevant to managers (Stevens, 2002.). Common approaches to marine reserve planning rely heavily on the use of abiotic surrogates, or obvious structural components in delineating areas as high priority for protection. Historically, this has meant a strong bias towards highly productive or aesthetically appealing (mangroves, seagrass beds, coral reefs) habitats as candidates for protection (Agardy, 1995). By this approach, assemblages such as the one described in this study are entirely overlooked even though they may be of scientific and ecological significance.

In summary, this study challenges the widely held view of crinoids as essentially reefal fauna. The lack of any strong correlation between the distribution of this unusual assemblage with crude, but commonly used, abiotic surrogates gives added weight to the use of approaches to marine conservation based on biological distributions at relevant scales.

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