

**THE ECHINOID
Parechinus angulosus
AND ITS
ASSOCIATION
WITH OTHER
INVERTEBRATES**

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THE ECHINOID *Parechinus angulosus* AND ITS ASSOCIATION WITH OTHER INVERTEBRATES

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ABSTRACT

Echinoids are recognized as important components of temperate kelp forests because of the impact that they have by grazing. The provision of shelter by some echinoid species for both juvenile conspecifics and for other species of echinoids has been widely documented. The behaviour is thought to be important in the survival of these species. The role of echinoids as protective "nurseries" for several types of marine animals has also been suggested. Adult echinoids are supported 1 – 2 cm above the substrate by the oral spines, this leaves a gap under the echinoid where other organisms can shelter. This paper examines firstly what types of organisms associate with the echinoid *Parechinus angulosus* and the degree to which they display tight relationships vs. chance associations. Secondly, it explores how much selectivity of the echinoids was involved when compared to other physical shelters and open substrate. This was done by comparing differences in the species associated with level, flat rocks covered with crustose corallines; the holdfasts of *Ecklonia maxima*; sand, and under echinoids. The study was done at four sites in False Bay, Cape Peninsula, South Africa. Samples were collected on each habitat type by placing a bottle over the substrate and scraping the sample into the bottle. The organisms in each sample were identified under a microscope and counted. The available habitat at each site was surveyed by divers swimming 6 x 8m transects and noting the cover of a particular habitat falling under the tape measure. The total number of species and organisms for each site were compared using one-way and two-way ANOVA's on untransformed data. The availability of different habitat types at each site was compared, using one-way fixed-effects ANOVA. Results showed that there was no significant difference between habitat availability at the different sites. Results of the two way ANOVA's comparing site and habitat for individual species showed that the amphipod *Paramoera capensis* only occurred in significant numbers at one echinoid site. The fact that 65 % of this species had a colour variation that matched the echinoid, implied that the amphipod gains protection from predators by being associated with subtidal echinoids. This relationship is not obligate as this amphipod was found in other habitats. The echinoid *Parechinus angulosus* appears to have a dual habitat preference with juveniles less than 10 mm in diameter sheltering beneath adult conspecifics and juveniles greater than 10 mm in diameter sheltering in kelp holdfasts. The amphipod *Hyale grandicornis* occurred in significant numbers associated with echinoids and had a habitat preference for echinoids, suggesting that it has an important relationship with subtidal echinoids. The amphipod is a known grazer of macroalgae and thus it is possible that the amphipod gets access to a food resource in the form of drift kelp, which is trapped by the echinoid. If this is the case then the amphipod would also be gaining protection from predators by being associated with the echinoid as the amount of time it is exposed while foraging is minimal. No relationship was found between echinoids *Halitosis midae* this was contrary to previous work and what was expected as this relationship is thought to be an obligate one. An important question that needs to be answered by future research is whether the echinoid *P. angulosus* is a drift trapper or a grazer as it has important impacts on commensal associations.

(Sertosa?)

INTRODUCTION

Echinoids are recognized as important organisms in the ecology of temperate kelp forests, because of their impacts due to grazing (Tarr et al, 1996). Echinoid populations are controlled by a variety of predators including crabs, sea otters, lobsters and fish (Tegner and Dayton, 1971). If there are no echinoid predators then the echinoid populations can spread and denude kelp forests and create areas covered with crustose coralline algae called "urchin barrens". If echinoid populations decline because of disease or fishing pressure (Tegner and Dayton, 1991), the density or extent of the kelp beds may increase. Thus, the interaction between echinoids and their predators have important ecological implications for kelp forests. ~ 5x?

Fletcher (1987), showed that the removal of the echinoid *Centrostephanus rodgersii* resulted in a rapid increase in the amount of non-crustose algae in a subtidal region at Cape Banks, New South Wales, Australia. Initially after the echinoids were removed there was an increase in the recruitment of juveniles and overall density of the limpets *Patelloida alticostata*, *P. mufria* and *Cellana tramoserica*. However, approximately a year after the removal of the echinoids all the limpet species showed densities near zero. Thus, showing that the continued existence of significant populations of these limpets requires the presence of echinoids. ?

The provision of shelter by some echinoid species for both juvenile conspecifics and for other species of echinoids has been widely documented. Juveniles of the echinoid *Tetrapyrgus niger* have been found under the spines of the echinoid *Loxechinus albus* off the Chilean coast (Rodriguez and Ojeda, 1993), while in the USA in Washington State, adult *Strongylocentrotus franciscanus* (Agassiz) echinoids have been observed harbouring juvenile *S. droebachiensis* and *S. purpuratus* (Duggins, 1993). Juvenile red echinoids *Strongylocentrotus franciscanus* shelter under adult conspecific echinoids in British Columbia (Tegner and Dayton, 1977). This behaviour is thought to be important in the survival of juveniles of these echinoid species (Tegner and Levin, 1983).

The role of echinoids as "nurseries" for several types of marine animals has been suggested in several sources (Tegner & Dayton, 1977; Day, 1998.). The suggestion is that the spines of the adult echinoids form a protective canopy for the juvenile echinoids as well as for other species, such as clingfish, snails and chitons (Tegner and Dayton, 1977 and Day, 1998). Adult echinoids are supported 1 – 2 cm above the substrate by the oral spines, this leaves a gap under the echinoid where organisms can shelter (see Figure 1).

The pleustid amphipod *Parapleustes echinocus* (Tzetkova) is said to be an obligate symbiont of the echinoid *Strongylocentrotus polyacanthus* (Agassiz and Clark) and lives among the spines of the echinoid (Vader, 1978), while the podoceric amphipod *Dulichia rhabdoplastis* (McCloskey) builds detritus rods on the tips of *S. franciscanus* spines (Vader, 1978). The amphipods feed on diatoms that grow on the rods in summer. In winter, they filter the detritus or plankton from the surrounding water. There is apparently no nutritive relationship with the host and the amphipods may derive benefit from the

echinoids' spiny defense. It is also not yet known if this amphipod is a specific associate of this echinoid or if any other species of echinoid serves as a host, but all known records of *D. rhabdoplastis* are all within the range of *S. franciscanus*. The common European gammarid *Melita obtusata* (Montagu) has been recorded as associating with the echinoid *Echinus esculentus* (Linnaeus) off the Isle of Man. It is also reported associating with a number of starfish hosts in Sweden, although it also occurs as free-living, in nocturnal surface plankton, and on a few occasions living among the tentacles of the sea anemone species *Anemonia sulcata* (Brady and Robertson) and even among hermit crabs in Normandy (Vader, 1978). Thus, the relationship with the echinoid is not obligatory. On the other hand the relationship between *E. esculentus* and the European lysianassid *Euonyx chelatus* (Norman) has been described as that of an obligate symbiont but the nature of the association is completely unknown (Vader, 1978). The amphilocheid *Amphilocheus neapolitanus* (Della Valle) was found clinging to the distal parts of the spines of *Letechinus variegatus atlanticus* (Lamarck) in Bermuda (Vader, 1978). When the echinoid was dislodged the amphipods returned to the echinoid. No other data on the biology of this association have been published.

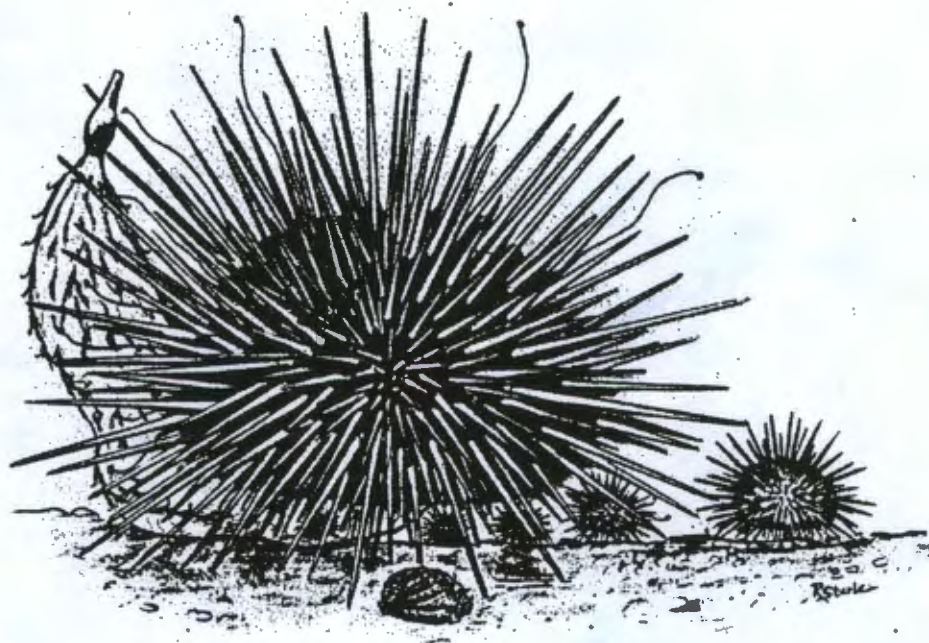


FIGURE 1: The spine canopy of an adult red echinoid, *Strongylocentrotus franciscanus*, provides shelter for juvenile echinoids and abalone (Tegner and Dayton, 1977)

Tegner and Dayton (1977) suggest that echinoid canopies provide protection against predation by sheephead fish and lobsters in Californian waters. They also found that the use of these echinoid "nurseries" is highest when the substrate gives little or no protection. Although experimental evidence showing predation as an important factor for amphipod associations with echinoids is

minimal, the observations that amphipods often adopt the colour of their hosts (Branch, 1975, Vader, 1995) may be an indication that predation is a factor.

Interactions between abalone and echinoids are less common, as populations of these species tend to be in competition with one another for the same food resource (Tegner and Levin, 1982). However, juvenile abalones have been found beneath the spines of echinoids on shallow subtidal reefs (Tegner and Dayton, 1977; Tegner and Butler, 1985; Tarr, 1989; SANCOR, 1996; Tarr et al, 1996 and Day, 1998).
Anthonis?

In the Western Cape of South Africa, it has been suggested that echinoid populations fulfill a similar role (Day, 1998). It has been established that the echinoid *Parechinus angulosus* (Leske) provides a vital role in the survival of the junior abalone *Haliotis midae* (Linnaeus) with > 98% of abalone of the size classes 3 – 20 mm shell length, being found beneath echinoids (Day, 1998). Two possible benefits to the juvenile abalone occurring from this association, are protection from predation and access to additional food captured by echinoids. Work done by Day (1998) on this relationship showed that removal of the echinoids led to dramatic reductions in abalone juveniles, thus indicating that this is a tight relationship.

Day (1998) found that when she removed echinoids by prizing them off the rocks, predators such as Klipvis (family: Clinidae) and dog sharks (*Paroderma* sp. and *Haploblepharus pictus*) consumed some of the exposed animals that had been sheltering under echinoids. These animals included chitons, amphipods and small haliotids namely *H. spadicea* and the juvenile *H. midae*.

A study done by Stobie (1998) looked at amphipod commensalisms with marine invertebrates in the South Western Cape. He found that the echinoid *Parechinus angulosus* had a wide range of amphipods associated with its external surfaces. Some of the species would hold tenaciously to their host even when their host was removed from the water. However, the habitat preferences of most of the amphipod species were known and the fact that they were often found in other types of habitats unassociated with the echinoid, meant that the association was facultative.

The aim of this paper is firstly to see what type of organisms associate with the echinoid *Parechinus angulosus* and the degree to which they have tight relationships vs. chance associations. Following on from that, I tested how much selectivity is involved in the association when compared to other physical shelters and open substrate. This was done by investigating whether there were differences in the species associated with *P. angulosus* compared with level, flat rocks covered with crustose corallines; in the holdfasts of *Ecklonia maxima*; and in sand. The study was done at four sites in False Bay, Cape Peninsula, South Africa.

METHODS AND MATERIALS

SITES

The research was carried out by divers sampling from April to late December 2000, at four selected sites in False Bay. These were between Simons Town and Cape Point at the following areas: Miller's Point A (MPA) ($34^{\circ} 13' 48'' : 18^{\circ} 29' 04''$) and Miller's Point B (MPB) ($34^{\circ} 13' 50'' : 18^{\circ} 29' 05''$), Outer Outer Castle rock (also known as Bakoven rock) (OOC) ($34^{\circ} 14' 07'' : 18^{\circ} 29' 34''$) and Roman Rock Lighthouse (RRL) ($34^{\circ} 10' 55'' : 18^{\circ} 27' 40''$) (See Figure 2). These sites were selected as previous studies have shown that echinoids occur in these areas (Day, 1998) and a series of 10 preliminary dives in March 2000 showed that echinoids occurred in these areas in sufficient densities to be sampled. The sites were situated around kelp beds (primarily *Ecklonia maxima* (Osbeck) Papenfuss and *Laminaria pallida* (Greville ex. J. Agardh)). The depths of the sites varied between 2 – 12 m. Divers dived from a boat and each dive was done between 09h00 – 12h00 at low tide.

?

GENERALITY OF RELATIONSHIP

? The first phase of the study was stratified random sampling of echinoids at Miller's Point, to identify the organisms that occur under them and to calculate the minimum number of echinoids needed to compare relationships of the organisms in different areas. To do this on one dive, divers removed 120 echinoids randomly from flat rock covered with crustose coralline algae at Miller's Point. These echinoids were then analysed in the laboratory and the total numbers and species of organisms found associated with echinoids were determined and used to calculate the minimum number of samples required for phase two. The reason that the sampling is stratified is that echinoids occur only on thin and thick crustose coralline algae (Day, 1998).

To sample the organisms under the echinoids accurately, the echinoids were removed by a diver by placing a collecting bottle (as shown in Figure 3) over the echinoid and then lifting the echinoid and scraping the substrate that the echinoid was on with a paint scraper that was bigger than the diameter of the bottle (60.5 mm).



FIGURE 3: A collecting bottle

Samples of other substrate types were taken the same way with the diver placing the collecting bottle on the substrate and then scraping with a paint scraper to collect a layer of the substrate type and its associated organisms. In this way, samples were taken of echinoids, level crustose coralline, sand and kelp holdfasts. Samples on kelp holdfasts were obtained by coring the collecting bottle into the holdfast and then scraping away at the hold fast so that the paint scraper could be placed under the bottle. Once a sample had been obtained the lid of the bottle was placed over the scraper and the scraper was carefully removed to ensure that no organisms escaped. The bottom of each jar comprised of 265 μ m mesh, which allowed water to flow through the bottle while the echinoid and its associated organisms remained in the bottle. This

also prevented the water from displacing organisms around the echinoid as the collecting bottle was lowered over the echinoid. *what sat?*

The material in each collecting bottle was subsequently filtered through a 265 μ m mesh sieve to collect the organisms. The samples were then taken to the laboratory where they were identified under a microscope using Day, (1974), Griffiths (1976), Kensley (1978) and Branch et al (1994) and counted. The diameter of the shell (excluding spine length) of each echinoid was measured (with a pair of calipers that read to 0.1 mm) and recorded.

~~Mention must be made that the holothuroid *Pseudocnella insolens* was found in two forms, either adults or adults with large numbers of juveniles. This species broods its young in pockets in its skin or often the young cling to the surface of the parent. Because of this, all young of this species were ignored and only the adults counted when they were present.~~

TIGHTNESS OF RELATIONSHIPS

The second phase of the project was to see if the relationships between invertebrates and urchins were specific or chance associations. To do this, twenty-five samples (this being the optimal number that was determined from the first phase of the study) of each substrate type were taken using stratified random sampling. The substrates examined included (1) those under echinoids, (2) on or in the holdfasts of *Ecklonia maxima*, (3) on sand and (4) on flat rock covered with crustose corallines. This was done at each of the four study sites.

The samples were then analyzed in the laboratory, where the number and species of organisms was recorded.

HABITAT EFFECTS

This set of surveys examined the possibility that, apparent preferences for certain substrate types may simply reflect the relative availability of those substrates.

To answer this question, the availability of all habitat types was assessed. The measurements of these habitat types were obtained by descending a buoy line anchored to the bottom of the study area. Two divers then swam out with a tape measure for 8 m in any direction from the anchor and recorded the total length of each substrate type falling within 5 cm on either side of the tape measure. This was repeated a total of six times at each site. Measures of the total area of each of the following habitat types were taken at each site:

Shale, Sand, Gravel, Small rocks (longest side being 10 cm), Flat rock, Vertical rock, Kelp holdfasts, Crevices (includes sheltered areas between adjoining rocks), "under rock" areas (areas under rocks that could be rolled over by a diver), Sponge, Coralline algae, Echinoids and Polychaete mats.

The areas were added for each of the substrate types mentioned above and converted to a percentage of total area available for animals. Echinoids were

included as a separate habitat type, as the area under them was being investigated and thus it was not measured as a coralline substrate.

DATA ANALYSIS

The total number of species and organisms for each site were compared using ANOVA on untransformed data. The availability of different habitat types at each site was compared, using one-way fixed-effects ANOVA. All statistical analyses were performed using STATISTICA v. 6.0 software package for Windows.

RESULTS

MINIMUM SAMPLE NUMBER FOR ALL SUBSTRATE TYPES

To calculate the minimum number of samples to take from each substrate type, for each site, a total of 120 echinoids were taken from Miller's Point and the number of species under each echinoid was plotted cumulatively. Plotting the species cumulatively, the resulting curve allowed us to see how many samples determined any particular n of the total number of species found. The point at which the resulting curve plateaux means that further sampling should produce no new species. The results of this are shown in Figure 4.

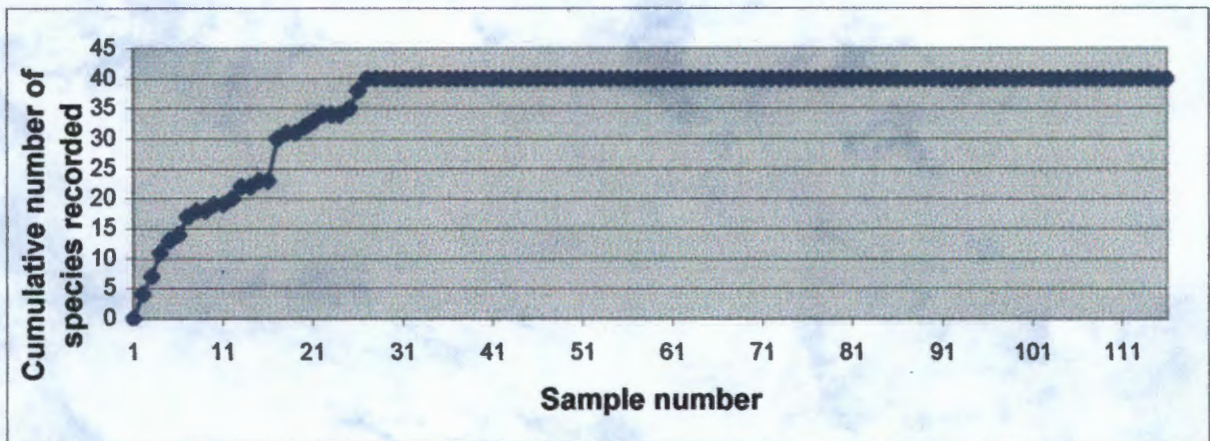


FIGURE 4: Cumulative frequency of species found associated with echinoids obtained from 120 echinoids sampled at Miller's Point

Figure 4 has a curve that levels off after 27 samples, meaning that in order to obtain all the species found at Miller's Point only 27 samples need to be taken. Due to the fact that this was an odd number and difficult to work with, the figure of 25 samples per habitat type was chosen. This figure accounts for 95 % of the total number of species found in the area.

AVERAGE NUMBER OF COMMENSALS PER ECHINOID

To determine the average number of commensals expected per urchin, the total number of organisms found associated with each of the 120 echinoids were counted, placed into a frequency table and grouped into size classes (See Figure 5).

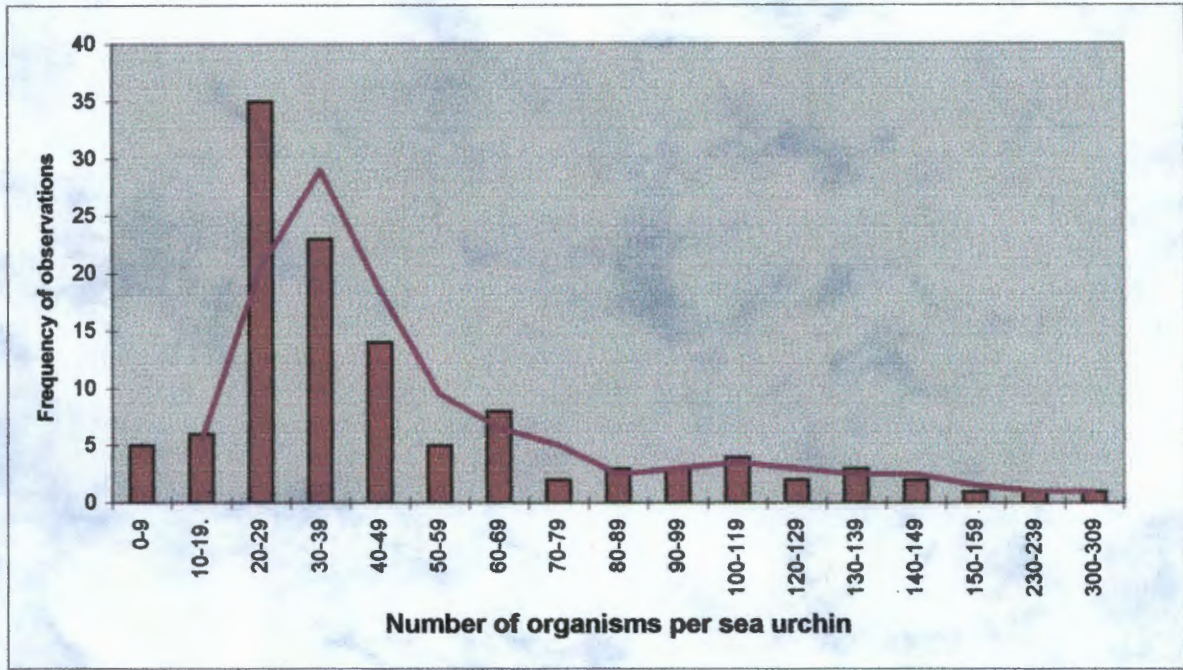


FIGURE 5: Bar graph of 120 echinoids sampled at Miller's Point grouped into size classes according to the frequency of the number of organisms under each echinoid. Note that the two frequency classes 230 – 239 and 300- 309 are not on the same scale as the rest of the classes. The line is a moving average trend line.

From Figure 5 we can see that the largest size class was 20 – 29 organisms per echinoid with the majority of the frequency being in the lower 20's. The moving average trend line in Figure 5 indicates that according to the size classes chosen, the number of commensals per echinoid would be around 29. As the majority of organisms in the 20 – 29 size class were in the lower twenties, if a smaller size class were chosen, this could change the average number of commensals per urchin to around 25.

RELATIONSHIP BETWEEN THE SIZE OF ECHINOID VS THE NUMBER OF ORGANISMS ASSOCIATED WITH IT

The relationship between the diameter of the echinoid and the number of organisms associated with each echinoid was investigated to see if larger echinoids harboured more organisms due their larger diameter. Larger diameter echinoids would have a larger area for protection under the echinoid than smaller diameter echinoids and would thus be expected to harbour more organisms. This relationship for each of the study sites can be seen in Figure 6.

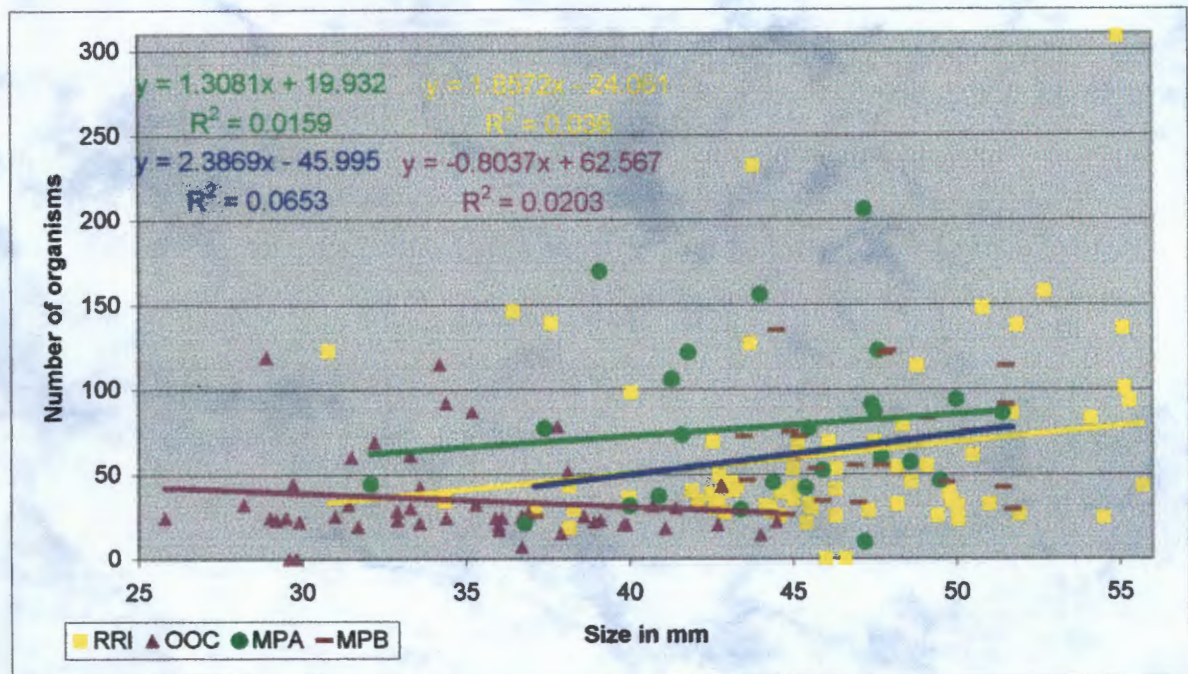


FIGURE 6: Relationship between the diameter of the echinoids (mm) and the number of organisms associated with each echinoid, at the four study sites. The r^2 values, as well as the equation for the regression lines for each site, are shown on the graph.

The regression lines and r-values were obtained by the computer and then p values from tables in Zar (1999) were found. Results that had a p value of 0.05 were considered significant.

TABLE1: r Values, df and p values for the regression lines for the sites shown in Figure 6

Site	r Value	Df	p Value
Outer Outer Castle	0.1425	48	0.2 – 0.5
Roman Rock Lighthouse	0.1897	68	0.1 – 0.2
Miller's Point A	0.1261	24	> 0.5
Miller's Point B	0.2555	24	0.2 – 0.5

The regression lines for all four study sites show that there is no relationship between the size of the echinoid and the number of organisms associated with them.

The average diameter of echinoids and the average number of organisms associated with the echinoids was investigated to see if any site was significantly different from another in this regard. This was done using a breakdown 1-way ANOVA followed by a TUKEY test HSD for unequal n.

The mean diameters of the echinoids differed significantly between sites (ANOVA: $df = 3$, $F = 59.84956$, $p = 0.000185$), and a TUKEY test was performed. The results can be seen in Table 2. Outer Outer Castle differed significantly from the other sites in that the mean diameter of its echinoids was smaller than those obtained for the other sites. The other three sites did not differ significantly from each other.

TABLE 2: Results of TUKEY test comparing mean diameter of the urchins at each of the sites. Only significant values are shown

SITE	OOC P VALUE	MEAN DIAMETER mm	STD DEV mm
OOC	—————	34.96	4.6
RRL	0.000008	45.82	5.4
MPA	0.000008	44.15	4.6
MPB	0.000008	47.16	3.4

The total number of animals under per echinoid differed significantly between sites (ANOVA: $df = 3$, $F = 6.999545$, $p = 0.000185$). A TUKEY test (shown in Table 3) showed that Outer Outer Castle was significantly different from all the other sites due to the fact that it had a smaller average number of organisms associated with each echinoid. None of the other three sites differed significantly from each other.

TABLE 3: Results of TUKEY test comparing total number of organisms under echinoids at each site. Only significant values are shown.

SITE	OOC P VALUE	MEAN TOTAL PER URCHIN	STD DEV
OOC	—————	34.49	25.99
RRL	0.005338	61.03	52.99
MPA	0.000264	77.68	48.49
MPB	0.012995	66.56	31.61

COMPARISONS OF ORGANISMS WITHIN HABITATS

SPECIES ASSOCIATED WITH ECHINOIDS

To see which species associated with echinoids were present in significant numbers, all sites were analysed by a 1-way ANOVA. The results of the ANOVA's for all the echinoid habitats can be seen in Table 4.

TABLE 4: Results of ANOVA comparing numbers of organisms at each echinoid site

Site	df	F Value	p Value
Outer Outer Castle	3024	35.03783	0.001
Roman Rock Lighthouse	4284	27.83362	0.001
Miller's Point A	1512	35.80296	0.001
Miller's Point B	1512	9.48863	0.001

Table 4 shows that there are significant differences between the numbers of organisms of a particular species associated with echinoids at all four sites. To see which organisms these were, a TUKEY honest significant difference test was performed. The results for all the echinoid habitats are shown in Table 5. Species that occurred in significant numbers are marked in red. Table 5 also shows the results of what species were found associated with the echinoids for each site, as well as giving the mean values and the standard deviations. Where the cells are blank and have no values this means that the species in the list did not occur at that particular site.

The species that which is listed as Gastropod? *Aetuniella nigra* is a species of gastropod that has been identified by description only and still requires further identification. The last five species on the list were unidentifiable as they were either juveniles or females or had too many missing limbs to make an accurate identification possible.

TABLE 5: Full species list for the all organisms found under echinoids at each of the study sites. Red text denotes which species were present in significant numbers. A = average, V = standard deviation of the average. (See Appendix 10.4, for Species Authorities)

SPECIES	OOC		RRL		MPA		MPB	
	A	V	A	V	A	V	A	V
<i>Amaryllis macrophthalma</i>	2.8	4.2	6.0	6.8	1.0	1.2	0.4	0.6
<i>Ampelisca brevicornis</i>					0.6	1.0	0.1	0.6
<i>Amphipholis squamata</i>							0.04	0.2
<i>Anatanais graclis</i>	1.3	3.4	1.3	2.7	1.8	1.9	3.0	2.9
<i>Arabella iricolor</i>								
<i>Aulacomya ater</i>	0.3	1.1	0.2	0.7		0.2		
<i>Burnupena</i> sp.			0.7	2.2		0.2		
<i>Caprella danlevski</i>	0.6	1.4	0.6	0.8				
<i>Caprella equilibra</i>	0.1	0.4	0.2	0.4	0.2	0.4	0.04	0.2
<i>Ceradocus rubromaculatus</i>	0.7	1.6	2.8	4.6	0.4	1.1	0.04	0.2
<i>Chaka leoni</i>	0.1	0.3	0.2	0.5				
<i>Chiton tulipa</i>								
<i>Cumacea</i> sp.	0.4	1.1	0.2	0.7	0.04	0.2		
<i>Cymadusa filosa</i>							0.1	0.3
<i>Cymodoce uncinata</i>							0.04	0.2
<i>Cyproidea ornate</i>					3.7	2.9	0.8	1.6
<i>Dendrofissurella scutellum</i>					0.04	0.2		
<i>Diogenes</i> sp.								
<i>Dynamenella ovalis</i>	0.2	0.8			0.04	0.2		
<i>Exosphaeroma planum</i>	0.2	0.5	2.8	4.3	1.2	1.9	0.6	1.5
Gastropod? <i>Aetunialla nigra</i>	0.1	0.3	1.6	2.6	0.5	1.2	0.04	0.2
<i>Golfingia capensis</i>	0.2	0.6	0.7	3.0	0.1	0.4		
<i>Haliotis midae</i>	0.02	0.1	0.4	2.5	0.3	1.1	0.1	0.3
<i>Helcion petunculus</i>			0.6	1.2			0.1	0.4
<i>Hyale grandicornis</i>	14.8	14.1	12.5	11.9	61.3	49.7	59.8	29.7
<i>Iphimedia gibba</i>								
<i>Jaeropsis stebbingi</i>	0.8	2.6	1.7	3.2	0.4	1.1		
<i>Lepidonotus semitectus clava</i>	0.2	0.5	0.02	0.1				
<i>Liljeborgia palmata</i>	0.4	1.1	0.2	0.7	0.04	0.2		
<i>Lysianassa ceratina</i>	0.6	1.3	1.4	1.8	0.7	0.9		
<i>Maera inaequipes</i>	0.02	0.1						
<i>Nebalia capensis</i>	0.3	0.8	1.2	2.3	0.04	0.2	0.04	0.2
<i>Nemertea</i> sp.					0.04	0.2		
<i>Nephtys</i> sp.	0.3	0.9	0.1	0.8	0.2	0.5	0.2	0.6
<i>Notasellus capensis</i>	2.0	4.9	0.5	1.2	0.04	0.2		
<i>Ochlesis lenticulosus</i>			0.4	1.0			0.04	0.2
<i>Ophionereis dubia</i>								
<i>Ostracod</i> sp.	0.1	0.4	2.4	9.8	1.0	1.7	0.2	0.6
<i>Panathura punctata</i>								
<i>Parechinus angulosus</i>	0.1	0.3	0.7	1.1	0.2	1.0	0.2	0.6
<i>Paridotea rubura</i>					0.04	0.2		
<i>Parisocladus perforatus</i>	0.1	0.7			0.1	0.4	0.1	0.3
<i>Paramoera capensis</i>	0.4	1.1	3.6	5.9	0.04	0.2	0.04	0.2
<i>Patella miniata miniata</i>								

<i>Pseudocnella insolens</i>	0.2	0.6	0.7	0.9	0.6	0.9	0.1	0.3
<i>Pinctada capensis</i>	0.02	0.1	0.04	0.2				
<i>Plagusia chabrus</i>								
<i>Pleurobranchaea tarda</i>								
<i>Spaeramene polytylotos</i>					0.04	0.2		
<i>Syllis variegata</i>	0.06	0.3	0.3	0.7				
<i>Tanystylum brevipes</i>								
<i>Tellina gilchristi</i>	0.3	0.7	1.2	4.2	0.04	0.2		
<i>Temnophilias capensis</i>	0.1	0.3			2.2	10.8		
<i>Thelepus</i> sp.			0.3	1.7	0.2	0.6		
<i>Tricolia neritina</i>	0.06	0.3	0.5	1.2				
<i>Turbo cidaris cidaris</i>	0.7	2.9	0.7	1.7	0.04	0.2	0.04	0.2
<i>Venus verrucosa</i>								
<i>Volvarina zonata</i>					0.1	0.3		
Eusiridae/ Gammaridae sp. ...?	3.4	5.2	6.2	9.7	0.1	0.4	0.2	0.6
Eusiridae/ Gammaridae sp. ...??	2.4	4.6	3.6	6.2	0.2	0.6	0.1	0.4
red dot amphipod sp. ...?			4.6	8.3	0.1	0.4		
Recently settled hermit crab zoea larva								
Mysidacea sp. ... ?								

The only species that occurred in significant numbers at all urchin sites was *Hyale grandicornis*. This species occurred in large numbers under most echinoids at all the sites with the average number of individuals under an echinoid at each site being larger than twelve and with the two Miller's Point sites having an average number of individuals greater than 59. This average number of individuals for this species was by far the largest average number encountered for any species in all habitats and sites.

To see if this relationship is because the echinoids are providing a suitable habitat or if it was just because there was no other habitat available all other habitat types at the sites were analysed using the same methods.

SPECIES ASSOCIATED WITH SAND HABITATS

To see which species were present in sand habitats in significant numbers, all sites were analysed by a 1-way ANOVA. The results of the ANOVA's for all the sand habitats can be seen in Table 6.

TABLE 6: Results of ANOVA comparing numbers of organisms at each sand site.

Site	df	F Value	p Value
Outer Outer Castle	1512	19.45980	0.00
Roman Rock Lighthouse	1512	23.67099	0.00
Miller's Point A	1512	9.661847	0.00
Miller's Point B	1512	25.64592	0.00

As with the echinoid site there are some species that occur in significant numbers in all the sand habitats at all of the sites. To identify these species, a TUKEY honest significant different test was performed. The results for all the sand habitats are shown in Table 7. Species that occurred in significant numbers are marked in red. This table also shows the results of which species were found present in sand habitats for each site, as well as giving the mean values and the standard deviations.

TABLE 7: Full species list for the all organisms found in sand habitats at each of the study sites. A = average, V = standard deviation of the average.

SPECIES	OOC		RRL		MPA		MPB	
	A	V	A	V	A	V	A	V
<i>Amaryllis macrophthalma</i>	1.8	0.9	0.2	0.5	0.6	0.7	0.2	0.4
<i>Ampelisca brevicornis</i>	0.2	0.4	0.2	0.4	0.8	0.9		
<i>Amphipholis squamata</i>	0.8	0.8	0.5	0.6	0.6	0.8	0.04	0.2
<i>Anatanais graclis</i>			4.7	4.6				
<i>Arabella iricolor</i>			1.1	1.9	0.1	0.3	0.04	0.2
<i>Aulacomya ater</i>	1.0	1.2	0.7	1.8	0.1	0.3	0.4	0.6
<i>Burnupena</i> sp.	1.5	1.1	0.6	0.8	0.3	0.6	1.8	1.2
<i>Caprella danlevski</i>	0.1	0.3						
<i>Caprella equilibra</i>					0.1	0.4		
<i>Ceradocus rubromaculatus</i>					0.04	0.2	0.04	0.2
<i>Chaka leoni</i>								
<i>Chiton tulipa</i>					0.04	0.2	0.04	0.2
<i>Cumacea</i> sp.	0.3	0.7					0.1	0.3
<i>Cymadusa filosa</i>	0.1	0.3	0.3	0.6				
<i>Cymodoce uncinata</i>	1.7	3.3	0.04	0.2			0.04	0.2
<i>Cyproidea ornate</i>	0.3	0.7	0.4	0.9	1.0	1.6	0.1	0.3
<i>Dendrofissurella scutellum</i>							0.1	0.3
<i>Diogenes</i> sp.							0.3	0.5
<i>Dynamenella ovalis</i>	0.3	0.6			0.2	0.5	0.3	0.6
<i>Exosphaeroma planum</i>	1.0	1.4			0.4	0.8	1.5	2.6
Gastropod? <i>Aetuniella nigra</i>	2.4	1.2	2.3	2.0	1.9	1.9	4.2	3.2
<i>Golfingia capensis</i>	0.4	0.8	2.0	1.8			1.2	1.2

<i>Haliotis midae</i>								
<i>Helcion petunculus</i>	1.3	1.3	2.0	1.1	0.4	0.8	1.9	1.5
<i>Hyale grandicornis</i>					0.7	1.3		
<i>Iphimedia gibba</i>	0.04	0.2						
<i>Jaeropsis stebbingi</i>			0.1	0.3				
<i>Lepidonotus semitectus</i> <i>clava</i>								
<i>Liljeborgia palmata</i>					0.04	0.2		
<i>Lysianassa ceratina</i>	1.5	1.4	0.2	0.5	0.8	1.7	0.1	0.3
<i>Maera inaequipes</i>					0.0	0.2		
<i>Nebalia capensis</i>	1.8	1.9			0.1	0.4		
<i>Nemertea</i> sp.					0.2	0.7	0.2	0.4
<i>Nephtys</i> sp.	1.1	1.7	0.8	0.8	0.6	1.0	1.7	1.5
<i>Notasellus capensis</i>					0.1	0.3		
<i>Ochlesis lenticulosus</i>								
<i>Ophionereis dubia</i>	0.8	0.8	0.3	0.5	0.5	0.7	0.04	0.2
<i>Ostracod</i> sp.	3.6	2.6	2.8	2.0	1.4	1.7		
<i>Panathura punctata</i>	0.04	0.2	0.04	0.2				
<i>Parechinus angulosus</i>								
<i>Paridotea rubura</i>								
<i>Parisocladus perforatus</i>	0.04	0.2					0.04	0.2
<i>Paramoera capensis</i>					0.4	0.9		
<i>Patella miniata miniata</i>	0.04	0.2						
<i>Pseudocnella insolens</i>								
<i>Pinctada capensis</i>	0.1	0.3	0.4	0.7			0.2	0.4
<i>Plagusia chabrus</i>								
<i>Pleurobranchaea tarda</i>					0.1	0.4		
<i>Spaeramene polytylotos</i>								
<i>Syllis variegata</i>					0.1	0.4	0.2	0.6
<i>Tanystylum brevipes</i>							0.04	0.2
<i>Tellina gilchristi</i>	2.9	2.1	2.2	1.7			0.4	0.6
<i>Temnophlias capensis</i>							0.1	0.4
<i>Thelepus</i> sp.			0.7	0.8	1.5	1.7	0.8	1.0
<i>Tricolia neritina</i>	1.4	1.3	2.0	1.2	0.2	0.5	2.3	1.9
<i>Turbo cidaris cidaris</i>	0.3	0.7	1.6	1.3	0.5	1.0	2.0	1.2
<i>Venus verrucosa</i>	0.1	0.3	0.2	0.5			0.1	0.4
<i>Volvarina zonata</i>	0.5	0.8	2.5	1.5	1.3	1.7	2.0	1.4
<i>Eusiridae/ Gammaridae</i> sp. ...?	1.0	1.4	0.4	0.9	0.4	0.9	1.0	1.2
<i>Eusiridae/ Gammaridae</i> sp. ...??	0.8	1.2	0.2	0.6	0.5	0.9	0.9	1.1
red dot amphipod sp. ...?	0.1	0.3			0.2	0.4		
Recently settled hermit crab zoea larva						0.2		
<i>Mysidacea</i> sp. ... ?			0.2	0.6			0.04	0.2

In the sand habitats at all the sites the dominant species tended to include more mollusc species and a few polychaete species. The gastropod species which is tentatively identified as *Aetuniella nigra* is the only species which is present in significant numbers at all the sites. The average number of organisms of a species is lower per sample than the echinoid sample averages.

SPECIES ASSOCIATED WITH CORALLINE HABITATS

To see which species were present in significant numbers in coralline habitats, all sites were analysed by a 1-way ANOVA. The results of the ANOVA's for all the coralline habitats can be seen in Table 8.

TABLE 8: Results of ANOVA comparing numbers of organisms at each coralline site.

Site	df	F Value	p Value
Outer Outer Castle	1512	7.587699	0.00
Roman Rock Lighthouse	1512	6.785474	0.00
Miller's Point A	1512	7.157508	0.00
Miller's Point B	1512	11.15744	0.00

All four coralline habitats had species that occurred in significant numbers. To identify these species, a TUKEY honest significant different test was performed. The results for all the coralline habitats are shown in Table 9. Species that occurred in significant numbers are marked in red. The table also indicates which species were present at each coralline habitat, as well as giving the mean values and the standard deviations.

TABLE 9: Full species list for the all organisms found in coralline habitats at each of the study sites. A = average, V = standard deviation of the average.

SPECIES	OOC		RRL		MPA		MPB	
	A	V	A	V	A	V	A	V
<i>Amaryllis macrophthalma</i>	0.8	0.8	0.8	1.3	1.3	1.2	0.4	0.5
<i>Ampelisca brevicornis</i>	0.4	0.6	0.1	0.3			0.4	0.5
<i>Amphipholis squamata</i>	0.2	0.5	0.5	0.8				
<i>Anatanais gracilis</i>	0.2	0.5	0.1	0.3	0.9	1.1	0.2	0.4
<i>Arabella iricolor</i>								
<i>Aulacomya ater</i>	0.1	0.4	0.3	0.6				
<i>Burnupena</i> sp.	0.5	1.3	1.5	2.7	0.3	0.6	0.04	0.2
<i>Caprella danilevski</i>	0.2	0.4	0.5	1.5	1.8	5.3	0.04	0.2
<i>Caprella equilibra</i>	0.3	0.6	1.3	2.2	2.0	5.3	0.2	0.4
<i>Ceradocus rubromaculatus</i>	0.2	0.4	0.4	1.4	1.5	2.2	0.1	0.3
<i>Chaka leoni</i>	0.04	0.2			0.5	1.4		
<i>Chiton tulipa</i>	0.1	0.6	0.2	0.6				
<i>Cumacea</i> sp.	0.1	0.4	0.1	0.4	0.2	0.6	0.04	0.2
<i>Cymadusa filosa</i>	0.04	0.2			0.2	0.5		
<i>Cymodoce uncinata</i>								
<i>Cyproidea ornate</i>	0.2	0.5	0.7	1.2			0.6	1.3
<i>Dendrofissurella scutellum</i>	0.1	0.4			0.8	1.2	0.04	0.2
<i>Diogenes</i> sp.	0.04	0.2						
<i>Dynamenella ovalis</i>	0.1	0.4	0.1	0.4				
<i>Exosphaeroma planum</i>	1.0	1.6	1.3	1.5	0.6	0.9	0.8	1.5
Gastropod? <i>Aetuniella nigra</i> .	2.3	2.1	4.0	7.6	2.3	2.5	2.1	2.2
<i>Golfingia capensis</i>	0.04	0.2	0.2	0.4	6.7	10.4	0.04	0.2

Haliotis midae	0.04	0.2	0.1	0.3	0.2	0.7		
Helcion petunculus					0.1	0.3		
Hyale grandicornis	0.04	0.2	0.1	0.3			0.04	0.2
Iphimedia gibba								
Jaeropsis stebbingi	0.04	0.2	0.3	0.7	0.1	0.3		
Lepidonotus semitectus clava	0.2	0.5	0.04	0.2	0.5	0.9		
Liljeborgia palmata	0.1	0.3	0.5	1.4	0.04	0.2	0.1	0.3
Lysianassa ceratina	0.4	0.8	0.4	1.2	0.6	1.4	0.2	0.5
Maera inaequipes	0.1	0.3	0.04	0.2	1.0	1.6	0.1	0.3
Nebalia capensis	0.04	0.2			0.04	0.2		
Nemertea sp.								
Nephtys sp.							0.1	0.4
Notasellus capensis	0.1	0.4	0.1	0.3	1.3	2.2		
Ochlesis lenticulosus					0.1	0.3		
Ophionereis dubia								
Ostracod sp.	0.5	1.0	0.2	0.5			0.3	0.6
Panathura punctata	0.04	0.2	0.1	0.3	0.1	0.4	0.04	0.2
Parechinus angulosus	0.04	0.2			0.04	0.2		
Paridotea rubra								
Parisocladus perforatus			0.2	0.6			0.04	0.2
Paramoera capensis	0.3	0.7	0.2	0.7	0.2	0.7		
Patella miniata miniata			0.04	0.2	0.6	1.7		
Pseudocnella insolens	0.7	1.0	1.8	1.2	0.7	0.8	0.7	0.8
Pinctada capensis					0.04	0.2		
Plagusia chabrus								
Pleurobranchaea tarda								
Spaeramene polytylotos								
Syllis variegata	0.04	0.2					0.2	1.2
Tanystylum brevipes	0.04	0.2			0.1	0.3		
Tellina gilchristi	0.3	0.7						
Temnophilias capensis	0.4	1.0	0.9	1.3			1.1	1.3
Thelepus sp.	0.1	0.3			0.2	0.4	0.1	0.4
Tricolia neritina	0.3	0.8	0.6	0.9	0.2	0.7		
Turbo cidaris cidaris	0.04	0.2	0.2	0.5	0.04	0.2	0.2	0.6
Venus verrucosa	0.1	0.3	0.7	2.1	0.3	0.5		
Volvarina zonata	0.0	0.2					0.1	0.3
Eusiridae/ Gammaridae sp. ...?	0.1	0.4	0.1	0.6	1.2	2.2		
Eusiridae/ Gammaridae sp. ...??	0.2	0.5	0.04	0.2	1.4	1.9	0.1	0.3
red dot amphipod sp. ...?	1.0	2.5	2.6	3.5	0.2	0.6		
Recently settled hermit crab zoea larva	0.04	0.2						
Mysidacea sp. ... ?								

Table 9 shows us that the only species to occur in significant numbers at all four sites was the gastropod *Aetuniella nigra*. The average number of organisms of a species per sample is also low when compared to echinoids except for the gastropod. However, the species diversity (50 species) is greater when compared to the echinoid habitat (40 species).

SPECIES ASSOCIATED WITH KELP HOLDFAST HABITATS

To see which species were present in significant numbers in kelp holdfasts, all kelp sites were analysed by a 1-way ANOVA. However, only two sites had *Ecklonia maxima* in sufficient densities to be sampled. In two dives done at Outer Outer Castle no kelp was found, while at Roman Rock Lighthouse although kelp was present, conditions prevented these samples from being taken. Thus, the only two sites that had samples for the kelp holdfast habitats are Miller's Point A and Miller's Point B. The results of these two ANOVA's are found in Table 10.

TABLE 10: Results of ANOVA comparing numbers of organisms at the two kelp sites.

Site	df	F Value	p Value
Miller's Point A	1512	12.74036	0.00
Miller's Point B	1512	24.76317	0.00

At both Miller's kelp sites, there were species that occurred in significant numbers. To identify these species, a TUKEY honest significant different test was performed. The results of these are shown in Table 11. Species that occurred in significant numbers are marked in red. The table also indicates which species were present in or on kelp holdfasts, as well as giving the mean values and the standard deviations.

TABLE 11: Full species list for the all organisms found in or on kelp holdfasts at the two Miller's Point sites. A = average, V = standard deviation of the average.

SPECIES	MPA		MPB	
	Ave	Std dev	Ave	Std dev
<i>Amaryllis macrophthalma</i>	2.0	2.5	2.0	1.2
<i>Ampelisca brevicornis</i>			2.0	1.2
<i>Amphipholis squamata</i>	0.6	1.1	1.5	1.7
<i>Anatanais graclis</i>	1.0	1.4	2.4	1.1
<i>Arabella iricolor</i>	1.5	2.3	0.6	1.2
<i>Aulacomya ater</i>	0.8	1.1	0.3	0.7
<i>Burnupena</i> sp.	1.4	2.0	2.0	1.1
<i>Caprella danilevski</i>	0.6	1.0	2.0	1.9
<i>Caprella equilibra</i>	4.2	5.0	4.0	4.0
<i>Ceradocus rubromaculatus</i>	1.3	0.9	1.6	0.9
<i>Chaka leoni</i>	0.1	0.3		
<i>Chiton tulipa</i>				
<i>Cumacea</i> sp.	0.5	1.0	0.2	0.6
<i>Cymadusa filosa</i>			0.5	0.8
<i>Cymodoce uncinata</i>	1.2	2.3	1.3	1.2
<i>Cyproidea ornate</i>	0.1	0.4	2.6	1.9
<i>Dendrofissurella scutellum</i>	0.6	1.4	0.2	0.5
<i>Diogenes</i> sp.				
<i>Dynamenella ovalis</i>	0.04	0.2	2.6	1.5
<i>Exosphaeroma planum</i>	2.0	2.9	5.8	3.3

SPECIES	MPA		MPB	
Gastropod? <i>Aetuniella nigra</i>	2.4	2.7	9.8	4.8
<i>Golfingia capensis</i>	4.0	2.9	3.4	5.3
<i>Haliotis midae</i>				
<i>Helcion petunculus</i>	2.6	3.3	1.2	1.4
<i>Hyale grandicornis</i>	0.4	0.8		
<i>Iphimedia gibba</i>				
<i>Jaeropsis stebbingi</i>	0.6	1.2	0.5	1.0
<i>Lepidonotus semitectus clava</i>				
<i>Liljeborgia palmata</i>			0.4	0.8
<i>Lysianassa ceratina</i>	0.2	0.4	2.9	1.6
<i>Maera inaequipes</i>	1.7	1.6	0.3	0.7
<i>Nebalia capensis</i>	0.1	0.3		
<i>Nemertea</i> sp.			0.2	0.5
<i>Nephtys</i> sp.			5.8	4.1
<i>Notasellus capensis</i>	3.8	4.1	0.5	0.6
<i>Ochlesis lenticulosus</i>	0.2	0.5	1.2	1.0
<i>Ophionereis dubia</i>				
<i>Ostracod</i> sp.	0.04	0.2	0.2	0.6
<i>Panathura punctata</i>	0.7	1.1	0.4	0.7
<i>Parechinus angulosus</i>	0.04	0.2	0.2	0.4
<i>Paridotea rubura</i>	0.04	0.2	1.1	1.4
<i>Parisocladus perforatus</i>	0.2	0.5	0.9	0.7
<i>Paramoera capensis</i>	0.2	0.5	0.9	0.8
<i>Patella miniata miniata</i>	0.6	0.9		
<i>Pseudocnella insolens</i>				
<i>Pinctada capensis</i>	0.04	0.2	0.4	1.8
<i>Plagusia chabrus</i>	0.6	1.3	0.2	0.5
<i>Pleurobranchaea tarda</i>	0.2	0.7		
<i>Spaeramene polytylotos</i>			0.2	0.7
<i>Syllis variegata</i>			1.0	1.3
<i>Tanystylum brevipes</i>	0.1	0.4		
<i>Tellina gilchristi</i>			5.4	4.3
<i>Temnophilias capensis</i>	3.2	3.3	0.8	0.9
<i>Thelepus</i> sp.	0.9	2.1	7.7	8.6
<i>Tricolia neritina</i>	4.3	4.4	1.3	1.7
<i>Turbo cidaris cidaris</i>	0.1	0.3	1.7	2.7
<i>Venus verrucosa</i>	0.6	1.3	0.4	0.8
<i>Volvarina zonata</i>			0.5	0.9
<i>Eusiridae/ Gammaridae</i> sp. ...?	1.0	1.3	2.2	1.3
<i>Eusiridae/ Gammaridae</i> sp. ...??	1.6	2.3	3.5	1.9
red dot amphipod sp. ...?	0.1	0.3		
Recently settled hermit crab zoea larva			0.1	0.4
<i>Mysidacea</i> sp. ... ?				

The isopod *Exosphaeroma planum*, the gastropod *Aetuniella nigra* and the polychaete *Golfingia capensis* were found at both sites in significant numbers.

COMPARISON OF ORGANISMS BETWEEN SITES

By running a one-way ANOVA to see which species occurred in significant numbers we encounter a problem: that is that it will only show which species are occurring in significant numbers at a site. It will miss species that are rare or that are territorial and have an obligate relationship with the echinoids and because of this they will occur under the echinoids in smaller densities. These species will not appear in significant numbers compared to the rest of the species so there is a limit to this type of analysis.

In order to see if the relationships that distinguished different habitats at different sites and to overcome the problem of missing rare or territorial species. A two-way ANOVA was run comparing sites and habitats. The species chosen to run the two-way ANOVAS were those species that were present in all four echinoid sites or had significant numbers at one or more of the echinoid sites (See Table 5). By running this type of ANOVA it is possible to establish whether a species is significantly more abundant in a particular habitat or site. By singling out these few species we avoid the error that would occur if we ran an ANOVA comparing all the species against sites and habitats. This is because one species will always differ from another in density and an interaction between habitats and species is almost inevitable as different species favour different habitats.

When comparing habitats at each of the four sites, both Outer Outer Castle and Roman Rock Lighthouse only had three habitat types. These were echinoids, sand and coralline. This is because divers were unable to locate or sample *Ecklonia maxima* as a habitat. The two Miller's Point sites each had four habitat types, the extra habitat being kelp holdfasts.

When running these tests, STATISTICA would not give results for the two-way ANOVAs. The results that are shown are obtained when a post hoc test was performed and this was the TUKEY HSD test for unequal n comparing sites against habitats.

Amaryllis macrophthalma

The Roman Rock Lighthouse Urchin habitat had significantly more of these individuals than any other site or habitat ($p < 0.002$ for all comparisons). This means that there were significantly more of these species at this site even though the numbers of this species were significant at several other sites and habitats. The average number of individuals per sample at Roman Rock Lighthouse Urchin was 6, with the rest of the habitats having less than 2.8 individuals per sample (See Table 5, 7, 9 and 11), the next largest number of individuals per sample was at Outer Outer Castle Urchin (2.8). This implies that these organisms tend to prefer urchin habitats although they are not exclusive to this habitat as they occurred in every site and in every habitat.

Anatanais gracilis

Roman Rock Lighthouse Sand habitat has significantly more of these individuals than any other site except Miller's Point B Urchin habitat ($p < 0.05$). The Roman Rock Sand habitat was the only sand habitat to have individuals of this species, and they occurred in significant numbers compared to the rest of the species at this site. Individuals of this species were present at all other sites and in all other habitats although not in significant numbers. Miller's Point B Urchin habitat had the second highest average number of individuals per sample and also had significantly more individuals than some of the other sites as did Miller's Point B Kelp, the results can be seen in Table 12. The fact that this species was found in high numbers at the Roman Rock Lighthouse Sand habitat and no other sand habitat, suggests that this is a special occurrence and that it has something to do with the site rather than the habitat. The fact that they occur in every other site and habitat except sand seems to suggest that at all other sites they are not exclusive to any particular habitat, but they do tend not to be found on sand.

TABLE 12: Results of TUKEY test comparing significant occurrence of individuals of *Anatanais gracilis* at sites and habitats.

SITE and Habitat vs. SITE and Habitat		p Value
RRL Sand	All	< 0.05
MPB Urchin	OOB Coralline	0.000898
MPB Urchin	OOB Sand	0.000165
MPB Urchin	RRL Coralline	0.000287
MPB Urchin	MPA Sand	0.000165
MPB Urchin	MPB Coralline	0.000675
MPB Urchin	MPB Sand	0.000252
MPB Kelp	OOB Sand	0.021375
MPB Kelp	RRL Coralline	0.033226
MPB Kelp	MPA Sand	0.021375
MPB Kelp	MPB Sand	0.027724

Caprella equilibra

Miller's Point A Kelp and Miller's Point B Kelp habitats had individuals that occurred significantly more than in any other habitat ($p < 0.02$ and $p < 0.0006$ respectively) except compared to each other. They were also found in the highest densities per sample at these two sites (4.2 and 4 individuals respectively). This shows that there is a strong preference for a kelp habitat by this species, despite the fact that they were found at all urchin and coralline habitats. This species also appears not to occur on sand, as the density of individuals at Miller's Point A, which was the only site to record this species on a sand habitat, was 0.1.

Ceradocus rubromaculatus

Roman Rock Lighthouse Urchin habitat had significantly more individuals than all sites ($p < 0.007$), except Miller's Point A Coralline, Miller's Point A Kelp and Miller's Point B Kelp. The density of individuals at all sites except Roman Rock Lighthouse was less than 1.7. The organisms occurred in all urchin, coralline and kelp habitats, Milers Point A and B were the only two sand habitats to have individuals of this species occurring. This implies that there is no real habitat preference displayed by this species.

Exosphaeroma planum

Miller's Point B Kelp has significantly more individuals than all sites ($p < 0.0006$). Other habitats that were significantly different are shown in Table 13. Densities of individuals were significant in all habitats at one or more sites, thus implying no real habitat preference by this species.

TABLE 13: Results of TUKEY test comparing significant occurrence of individuals of *Exosphaeroma planum* at sites and habitats.

SITE and Habitat vs. SITE and Habitat		p Value
MPB Kelp	All	$P < 0.0006$
RRL Urchin	OOC Urchin	0.000036
RRL Urchin	RRL Sand	0.004410
RRL Urchin	MPA Sand	0.032514
RRL Urchin	MPB Kelp	0.000516

Gastropod: *Aetuniella nigra*

Several habitats differed from others in terms of numbers of individuals per habitat and this can be seen in Table 14. This species occurred at all four sites and in all habitat types. The urchin habitat was the only habitat where this species did not occur in significant numbers. However, for all the other sites and habitat types it did occur in significant numbers. This suggests a negative preference for urchin habitat, even though they were associated with urchins at all the sites.

TABLE 14: Results of TUKEY test comparing significant occurrence of individuals of *Anatanais gracilis* at sites and habitats.

SITE and Habitat vs. SITE and Habitat		p Value
RRL Coralline	OOC Urchin	0.000215
RRL Coralline	MPA Urchin	0.001816
RRL Coralline	MPB Urchin	0.000173
RRL Coralline	MPB Kelp	0.000029
MPB Sand	OOC Urchin	0.000082
MPB Sand	MPA Urchin	0.001816
MPB Sand	MPB Urchin	0.000070
MPB Kelp	All	0.000030

Haliotis midae

There were no significant numbers of individuals occurring at any of the sites or habitats. This species did not occur on sand or kelp habitats at any of the sites. The species was found associated with urchins at all the sites and was found in slightly higher densities than at coralline habitats. The species was not found at Miller's Point Coralline habitat. This indicates that the species has a slight preference for urchin or coralline habitats, possibly preferring urchin habitats although there was no significant difference between the two habitats.

Hyale grandicornis

Miller's Point A Urchin and Miller's Point B Urchin habitats had individuals that occurred significantly more than in any other habitat ($p < 0.000030$ and $p < 0.000030$ respectively) except compared to each other. Although this species occurred at other sites and habitats, it only occurred in significant numbers at all the echinoid habitats and this analyses shows that the numbers of this species were greater at Miller's Point A and Miller's Point B echinoid habitats. This indicates a preference for an echinoid habitat by this species particularly at Miller's Point.

Nebalia capensis

Outer Outer Castle Sand and Roman Rock Lighthouse Urchin had significantly more individuals than in any other habitat ($p < 0.000067$ and $p < 0.009$ respectively) except compared to each other. Densities at all other sites and habitats were low and this implies that the species has no real preference for any of the habitats investigated.

Nephtys sp.

Miller's Point B Sand habitat had significantly more individuals than all other habitat types except other sites which had sand habitats ($p = 0.01$). This shows that the species has a definite preference for a sandy habitat. Miller's Point B Kelp also had significantly more of these individuals than any other site ($p = 0.000029$) and the density of individuals was highest at this site, but it was not found in the other kelp habitat and this means that it could be a site related occurrence.

Ostracod sp.

There was no significant numbers of individuals occurring at any of the sites or habitats. This means that at no particular site did this species show a preference for a particular habitat. This was despite the fact that it occurred in significant numbers in a number of sites and habitats.

Parechinus angulosus

This species only occurred in significant numbers at Roman Rock Lighthouse Urchin habitat ($p = 0.009$). The species were not found in any sand habitats and they occurred in very low numbers on coralline habitats and in kelp habitats although, the other urchin habitats had higher densities of these individuals than either the kelp or coralline habitats.

The results from this analysis suggest that conspecifics of this species shelter beneath adults. One interesting point to note is that echinoids greater than 10 mm in diameter of this species were found sheltering between the haptera of *Ecklonia maxima*. Individuals of this species that were found associated with echinoids, were all less than 10 mm diameter. Since all the individuals of this species that were larger than 10 mm in diameter were found in kelp holdfasts and all individuals smaller than 10 mm diameter were found beneath echinoids this suggests that there is a diameter limit to the size of the juveniles that can shelter beneath adult echinoids. The analyses that have been performed here will not show this habitat preference corresponding to the size of the echinoid and this probably requires further work and testing. Also, the sample number obtained in this study is too small to conclude if this is a significant relationship or not.

Paramoera capensis

This species also only occurred in significant numbers at the Roman Rock Lighthouse Urchin habitat ($p = 0.009$). This species was found in all habitat types at most sites although it was found in higher densities at the urchin habitats. Thus, there could be a slight relationship between urchins and this species but the relationship is not obligate.

Pseudocnella insolens

Roman Rock Lighthouse Coralline habitat had significantly more individuals than all sand and kelp habitats ($p = 0.000029$). There was no significant difference between Roman Rock Lighthouse Coralline habitat and all other coralline habitats. There was a slight significant difference between this habitat and other urchin habitats ($p = 0.04$). The species did not occur in sand or kelp habitats and it occurred in lower densities in urchin habitats when compared to coralline habitats. This shows that the species has a definite preference for coralline habitats although it is found with echinoids. This however, could be because echinoids also occur on coralline algae.

Temnophilias capensis

Miller's Point A Kelp habitat differed significantly from all other habitats ($p = 0.008$), except Roman Rock Lighthouse Urchin, Miller's Point A Urchin, Miller's Point B Urchin and Miller's Point B Kelp. This result suggests that this species has a slight preference for habitats which are able to provide it with some form of physical shelter rather than being in an open habitat like coralline or sand.

Turbo cidaris cidaris

Roman Rock Lighthouse Sand, Miller's Point B Sand and Miller's Point B Kelp differed from others in terms of numbers of individuals per habitat and this can be seen in Table 15. This species occurred at all four sites and in all habitat types. The urchin and coralline habitats were the only habitats where this species did not occur in significant numbers or in very large densities. The sand habitats had the largest densities, also the fact that two of the sand habitats were significantly different from most habitats, suggests that there is a slight preference for a sand habitat by this species.

TABLE 15: Results of TUKEY test comparing significant occurrence of individuals of *Turbo cidaris cidaris* at sites and habitats.

SITE and Habitat vs. SITE and Habitat		P Value
RRL Sand	OOO Coralline	0.013839
RRL Sand	MPA Urchin	0.013839
RRL Sand	MPA Coralline	0.013839
RRL Sand	MPA Kelp	0.027321
RRL Sand	MPB Urchin	0.013839
MPB Sand	OOO Coralline	0.000384
MPB Sand	OOO Sand	0.006690
MPB Sand	RRL Coralline	0.002062
MPB Sand	MPA Urchin	0.000384
MPB Sand	MPA Coralline	0.000384
MPB Sand	MPA Sand	0.027321
MPB Sand	MPA Kelp	0.000899
MPB Sand	MPB Urchin	0.000384
MPB Sand	MPB Coralline	0.002062
MPB Kelp	OOO Coralline	0.006690
MPB Kelp	RRL Coralline	0.027321
MPB Kelp	MPA Urchin	0.006690
MPB Kelp	MPA Coralline	0.006690
MPB Kelp	MPA Kelp	0.013839
MPB Kelp	MPB Urchin	0.006690
MPB Kelp	MPB Coralline	0.027321

***Eusiridae/ Gammaridae* Species unknown Amphipod 1**

Roman Rock Lighthouse Urchin habitat had significantly more individuals than all sites ($p < 0.007$), except Outer Outer Castle Urchin, and Miller's Point B Kelp. The species occurred in all habitat types and at all sites. There were significant numbers of this species occurring in the sand habitats. Because of the significant numbers occurring in urchin, kelp and sand habitats, this species does not show a clear preference for a particular habitat.

***Eusiridae/ Gammaridae* Species unknown Amphipod 2**

Roman Rock Lighthouse Urchin and Miller's Point B Kelp differed significantly from a number of habitats. This can be seen in Table 16. This species occurred in all sites and habitats. The species shows a definite preference for either urchin or kelp habitats thus indicating that some form of physical shelter is required in its habitat choice.

TABLE 16: Results of TUKEY test comparing significant occurrence of individuals of *Eusiridae/ Gammaridae* Species unknown Amphipod 2 at sites and habitats.

SITE and Habitat vs. SITE and Habitat		p Value
RRL Urchin	OOC Sand	0.009891
RRL Urchin	RRL Coralline	0.005860
RRL Urchin	RRL Sand	0.013850
RRL Urchin	MPA Urchin	0.013850
RRL Urchin	MPA Sand	0.035664
RRL Urchin	MPB Urchin	0.008327
RRL Urchin	MPB Coralline	0.008327
MPB Kelp	OOC Coralline	0.016171
MPB Kelp	RRL Coralline	0.009794
MPB Kelp	RRL Sand	0.022296
MPB Kelp	MPB Urchin	0.013718
MPB Kelp	MPB Coralline	0.013718

Unknown red dot amphipod species

Roman Rock Lighthouse Urchin differed significantly from all other habitats ($p = 0.001$) except Roman Rock Lighthouse Coralline. This species had very low densities in the sand and kelp habitat and it occurred in significant numbers in both coralline and urchin habitats. This implies that this species prefers coralline habitats and that the species had a slight site preference for Roman Rock Lighthouse.

OBSERVATIONS

The amphipod *Paramoera capensis* displayed a variation in coloration, 65 % had colorings of purple, pink and white that were similar to the host echinoid *P. angulosus*, while the remaining 35 % had a brown coloration. These amphipods were also observed clinging to the host even when the echinoid was removed from the water. If an echinoid was knocked over by a diver the organisms were observed to quickly relocate to their original host or to another echinoid host.

This was also true of another amphipod *Hyale grandicornis* which was observed sheltering under the echinoids in large quantities. If the echinoid was overturned or removed these amphipods would, within two minutes locate another echinoid host and move beneath it. Only one was observed to be unable to find a host after this time and it sheltered beneath a piece of knobby coralline *Leptophytum ferox* that stood proud of the surface by 1 cm. A large proportion of these amphipods were egg-bearing or juveniles.

HABITAT AVAILABILITY

The area available at each study site was measured to see if the organisms preferred echinoids because other habitat types which would also provide sufficient shelter were not available. The habitat types were also measured at each site to see if the sites differed significantly from each other. The results can be seen in Table 24.

TABLE 24: Total percentage area of each substrate type measured at each of the four sites

Substrate	Roman Rock Lighthouse	Outer Outer Castle	Miller's Point A	Miller's Point B
Sand	16.6	0	39.1	0.4
Shale	1.1	0	0	0
Gravel	6.0	0	2.9	0.2
Small rock	0	0	4	2.7
Flat rock	12.5	32.3	10	0
Vertical rock	15.6	22.3	2.9	2.1
Kelp	0	0	1.8	5
Crevice	0.8	2.5	1.7	1
Under rock	2.1	2.1	0	0
Sponge	9.4	0	0	0.2
Coralline	21.3	23.3	40	60.2
Echinoid	7.7	17.5	3.9	15.2
Polychaete	3.6	0	1	0
Mussels	3.1	0	0	0
Foliar algae	0	0	0	12.9

The data did not have a normal distribution therefore the assumptions required to perform an ANOVA were not met. Therefore, a non-parametric test namely the Kruskal-Wallis one-way analysis of variance was used. A Chi Squared independent grouping test was performed: $df = 3$, $p = 0.2615$. Thus, there is no significant difference between the abundances of habitat types at the sites examined. All sites are therefore not significantly different in terms of habitat type distribution.

DISCUSSION

RELATIONSHIP BETWEEN THE SIZE OF ECHINOID VS THE NUMBER OF ORGANISMS ASSOCIATED WITH IT

There was no relationship between the size of the echinoids and the number of organisms associated with them (See Figure 6). This is contrary to the theory that as the echinoid's size and thus diameter increases, the area under the echinoid that is available to organisms should also increase. It must be said that this only holds true over the size classes of echinoids sampled spanning 25.8 mm to 55.7 mm. The relationship between diameter of the echinoid and the number of organisms under it may well hold true for echinoids with a smaller diameter.

Three of the four study sites had very similar echinoid size class population, namely, Roman Rock Lighthouse, Miller's Point A and Miller's Point B. The echinoids there also had a similar number of organisms associated with each of them. Outer Outer Castle however, had fewer organisms associated with the echinoids and the echinoids were also of a smaller mean diameter than the other sites. Although Outer Outer castle showed no relationship between increasing diameter and an increasing number of associated organisms. The fact that the mean diameter and the mean number of organisms associated with the echinoids were less than the other sites, suggests that the relationship between diameters of echinoids and numbers of associated organisms will hold true over a wider size range than examined.

SPECIES ASSOCIATED WITH ECHINOIDS

The number of commensal invertebrates associated with echinoids ranged from 0 – 309, with the average number per echinoid being around 22. This is a large number of individuals and this suggests that echinoids are important habitats and the numbers or densities of echinoids should be considered when working out the availability of habitats for invertebrate species.

There were a number of species that were found at echinoid habitats in significant numbers. These included amphipods *Amaryllis macrophthalma*, *Ceradocus rubromaculatus*, *Paramoera capensis*, the isopod *Exosphaeroma planum*, the seed shrimp *Ostracod* sp, the two unidentified amphipods Eusiridae/ Gammaridae sp. and the unidentified red dot amphipod sp. Although these species were found associated with echinoids in significant numbers the results of the two-way ANOVA's comparing sites against habitats for each of these species showed that they were not obligate to the echinoids and often had other habitat preferences.

Although it was found that the amphipod *Amaryllis macrophthalma* tended to prefer urchin habitats, they were not exclusive to the urchin habitat and were found in other habitat types.

The amphipod *Caprella equilibra* is thought to prefer the hold fasts of kelp as a habitat, although they were found on coralline and urchin habitats. This species did not occur on sand habitats.

The amphipod *Ceradocus rubromaculatus* did not appear to have any habitat preference and occurred on all habitats sampled.

The isopod *Exosphaeroma planum* also had no real habitat preference and occurred on all habitats sampled.

The gastropod which was tentatively identified as *Aetuniella nigra* tended to have a slight negative preference for urchin habitats.

The abalone *Haliotis midae* was expected to show a preference for echinoid habitat as a result of Day's 1998 results. However, analyses of the data did not show a significant preference for echinoid habitats and it is possible that the number of abalone juveniles found were too low to show this relationship.

The only positive significant preference for echinoid habitat was that all four echinoid habitats had significant numbers of the amphipod *Hyale grandicornis* present and none of the other habitats at any of the other sites had significant numbers of this amphipod. This suggests that the relationship between echinoids and this amphipod is a commensal one with the amphipod gaining some benefit from being under the echinoid. *H. grandicornis* is, however, found abundantly in foliar seaweeds and it has several known habitat types, thus this relationship cannot be seen as obligate and must rather be seen as facultative with the amphipod gaining some benefit from being associated with subtidal echinoids.

The leaf shrimp *Nebalia capensis* also did not show any preference for any particular habitat type.

The polychaete species *Nephtys* that is also called *Nephtys*' sand worms (Branch et al. 1990) showed a clear preference for the sand habitats. This result is not surprising as this species is often found in burrows in sand banks and sandy beaches.

The seed shrimp *Ostracod* sp also did not show any preference for a particular habitat type and occurred on all habitats.

The echinoid *Parechinus angulosus* appears to have a dual habitat preference with juveniles less than 10 mm in diameter sheltering beneath adult conspecifics and juveniles greater than 10 mm in diameter sheltering in kelp holdfasts. Unfortunately, this relationship could not be analysed further as the nature of the data did not allow a sufficient statistical analysis to be performed. This relationship will require further research to see if the results obtained are a true reflection of what is occurring.

The amphipod *Paramoera capensis* appeared to have a slight preference for echinoid habitats. This together with the fact that 65 % of the individuals found had colorations that matched their host suggests that this is a stronger relationship than is shown, although the relationship is not obligate. The amphipod is probably using the echinoid as shelter from predation as the coloration suggests some form of cryptosis.

The sea cucumber *Pseudocnella insolens* was found to prefer coralline habitats and did not occur in sand or kelp habitats. The species was found associated with echinoids but this could be because the echinoids occur on coralline algae. Branch et al, 1990, describe this species as occurring on shallow reefs and this is shown by the species preference for coralline habitats.

The louse amphipod *Temnophlias capensis* tended to be found in habitats that could provide it with some form of physical shelter, in this study these were the echinoid habitats and the kelp habitats. Branch et al, 1990, describe this species as occurring clinging to sponges and ascidians, on the underside of boulders and in gullies in intertidal pools. All these habitats provide this species with some form of physical shelter.

The turban shell *Turbo cidaris cidaris* tended to be found on sandy habitats, although they occurred on all habitats sampled.

The first unknown amphipod of the *Eusiridae/ Gammaridae* genus did not show any clear habitat preference for any of the habitats sampled. The amphipods were unidentifiable due to the large numbers of females and juveniles. The way in which we got to the genus names was because a characteristic of this genus is the loss of limbs and limb loss was prevalent in this species.

The second unknown amphipod of the *Eusiridae/ Gammaridae* genus had a habitat preference for habitats that provided physical shelter such and thus it occurred more often in kelp and urchin habitats. This species was also only identifiable to this level as it had lost a large number of limbs and individuals of this species consisted of juveniles and females.

The unknown red dot amphipod species all consisted of females, but they were very easy to identify as a group as they had a red dot on their first side plate. The species tended to be found on coralline and urchin habitats and was more abundant at the Roman Rock Lighthouse site.

HABITAT AVAILABILITY

The reason for sampling the different habitat types and their percentage cover over the whole area is to see if the relationships between the echinoids and their associated organisms were occurring due to a relative scarcity of an otherwise suitable habitat type for the organisms. The fact that all sites had similar habitat types and that they were not significantly different from each other (See Table 24), means that in the sites sampled, one can assume that the relationships observed were a true reflection of what was happening and not because a suitable habitat was too scarce for the organisms to colonize.

As a site, the Roman Rock Urchins often had significant numbers of organisms associated with them. A possible reason for this is that Roman Rock Lighthouse is a large exposed reef, and does not have a lot of shelter. Most of the commensals relationships could be occurring on the urchin habitat as there is a need for shelter at this site.

TYPES OF ASSOCIATIONS

An interaction between two organisms would be classified as commensalism if one organism (the host) provides resources for another organism, but in which the host suffers no tangible ill effects (Begon et al. 1990). The question which must be asked is: "What possible benefits could an organism gain by associating with an echinoid?" Resources the organism could gain include nutrition, reduced predation and the provision of a suitable micro-climate.

Vader (1978) suggested that many of the associations of amphipods with echinoderms have been formed by recent evolution of the amphipods and lack a long co-evolved history. Thus, an ecological approach must be used to categorize the possible benefits that organisms associating with echinoids would derive.

Nutritional benefits

Many of the associations are likely to have formed because the organism benefits by gaining access to a suitable food source. This could be by the organism consuming the echinoid's food or faeces, or because the activities of the echinoid cause food to become available for the organism. Day (1998), deduced that juvenile *Haliotis midae* sheltering under the echinoid *P. angulosus* gained access to drift kelp that they would otherwise be too small to obtain.

Reduced Predation

The organism could benefit from association with the echinoid due to the echinoid being less vulnerable to predators (because of its spines) than the organism. There are several recorded cases of this (Duggins, 1993; Rodriguez and Ojeda, 1993; Tegner and Dayton, 1977; Tegner and Levin, 1983; Vader, 1978). The fact that many of the individuals of the amphipod *Paramoera capensis* had coloration that was similar to the echinoid *P. angulosus*, while in intertidal habitats they usually adopt a brown coloration (personal observation; Stobie, 1998; Branch, 1975; Vader, 1995), suggests that these amphipods enjoy additional protection by being associated with the echinoid.

Substratum acquisition

The organism could benefit from the association with its host by obtaining a suitable substratum to inhabit.

Reduced Physical Environmental stress

By associating with the host, the organism could reduce the degree of variability and unpredictability in the environment. This category applies specifically to intertidal associations where the organisms gain protection from desiccation and solar radiation. Branch (1975) studied the relationships between amphipods and intertidal limpets *Patella* spp. The amphipod *Hyale grandicornis* was often found in the pallial cavities of *Patella* spp. but the relationship was only facultative as the amphipod benefited from having a suitable microclimate at low tide to help it escape desiccation and at high tide, the amphipod left its host. Other species, such as the copepod *Scatellidium patellarum*, the flatworm *Notoplana patellarum* are, however, solely associated with the limpets (G. M. Branch pers. comm.).

REASONS FOR THE ASSOCIATIONS

The reason for the association of *H. grandicornis* with the echinoid in a subtidal environment is not to reduce its environmental stress, as all the study sites were in subtidal areas, thus, the reasons most of the associations are occurring with the echinoids in the subtidal environment are for nutritional benefit or reduced predation and possibly substratum acquisition.

The availability of shelter appears to play an important role in the survival of juveniles. For example, juveniles of shelter-dependant echinoids such as *Centrostephanus coronatus* (Vader, 1978), which suffer high predation rates when shelter (in the form of crevices) is limited. The echinoids in this study contributed between 4 – 17 % of the total area available for shelter in this study (See Table 24). In the presence of echinoids, not only is more shelter available, but the shelter is distributed across the whole reef instead of being limited to crevices (which only supplied between 0.8 – 2.5 % of the area available for shelter in this study). Day (1998), suggested that the distribution of echinoids over a wider area than that covered by physical shelters such as crevices, might distribute organisms associated with the echinoids more evenly around the reef, thereby distributing their grazing on a food resource. More importantly, this distribution would have the effect of reducing the time (and thus the vulnerability to predation) spent by organisms traveling from a shelter to a grazing area. With organisms being distributed more evenly over a reef area, the organisms should be far enough apart to ensure that food would not become limiting in the vicinity of their shelter.

Another mechanism whereby the organisms could benefit from their association with echinoids is that the organisms gain access to additional food resources, thereby supplementing their diet. There are a number of possible ways in which this can occur. The first is by using the echinoid as a safe haven to grow food like the amphipod *Dulichia rhabdoplastis* which feeds of the detritus rods that it builds on the tips of *S. francisanus* spines (Vader, 1978). The second is to either feed off the echinoid faeces and or body secretions such as the haustoriid amphipod *Urothoe marina* (Bate) that feeds off secretions from the echinoid *Echinocardium cordatum* (Pennant) (Vader, 1978). The third way is either to eat the food that the echinoid does in the form of scraps that break off or to actively join in the feeding of the same food resource. This is probably the most likely reason for the associations of invertebrates with the echinoids.

It has been proposed by Day (1998), that *P. angulosus* traps drift kelp rather than grazing the benthic substrate. Velmirov et al, 1977 (in Day, 1998) attribute a debris-feeding role to *P. angulosus* as opposed to a grazer. This is contrary to the role that echinoids are thought to play as "key stone grazers" in some systems, where there is a close relationship between echinoid grazing and the maintenance or creation of large defoliated areas covered by crustose corallines (Tegner and Dayton, 1991).

The occurrence of drift kelp trapping by other species of echinoids has been noted in South American echinoids, *Loxechinus albus* (Tegner and Dayton, 1991). It has also been suggested that the echinoids in the giant kelp forests in Californian systems are normally sustained by drift kelp and only attack and graze living plants when drift kelp is limiting (Tegner et al, 1995 in Day, 1998). It has been suggested that the consumption of aged drift material is nutritionally superior to the consumption of fresh material. This is because the fresh material has not yet accumulated bacterial and diatom communities (Duggins and Eckman, 1994 in Day, 1998).

Day's (1998) experiments on "grazer" removal did not yield any of the expected responses from the algal community, thus, seeming to confirm her proposal that *P. angulosus* does not play the role of a grazer in Western Cape kelp bed systems. This is contrary to what Anderson et al (1997) found, which was that where there were high numbers of benthic grazers, the juvenile kelp sporophytes occurred on the holdfasts of adults rather than on rocks. In fact, there was a direct relationship between the juveniles on kelp holdfasts/juveniles on rocks and the density of grazers. They also found that the mean percentage cover of understory algae was inversely related to the grazer density (the main benthic grazers being the echinoid *P. angulosus*). Their results show that *P. angulosus* does play the role of a grazer in Western Cape kelp bed systems.

However, it has been suggested that the mode of feeding employed by urchins is dependant on food availability and that in the absence of drift material, a switch in feeding behaviour from drift trapping to active grazing is predictable. The critical factor driving this feeding behaviour switch is the ratio between drift availability and grazing pressure. A decrease in drift availability can trigger to switch to grazing on live kelp (Tegner and Dayton, 1991).

If *P. angulosus* is a drift trapper and not a grazer, this means that a theorized possible negative effect of echinoids on organisms associated with them is negligible. If *P. angulosus* grazed the substrate for micro flora with their powerful Aristotle's Lantern feeding apparatus, they could consume small underlying invertebrates or compete with other smaller grazers for food. By being a drift trapper even in the presence of high densities of urchins, the threat for organisms associated with the echinoids, of being consumed, is negligible. In fact, it has been noted that when urchins feed via drift trapping the movement of urchins is minimal (Day, 1998). Thus, organisms that shelter under *P. angulosus* may benefit from kelp trapped by the urchins.

Day, 1998 suggested that if the organisms can feed beneath the echinoids, either on the drift kelp caught by the urchins, or on the substrate beneath the urchins, they may in turn reduce or even eliminate their exposure to predation while grazing on an exposed reef. Thus, the organisms have the perfect mobile shelter under which to feed. If the organisms do feed beneath the echinoids then this will have effects on their foraging behaviour, which will need further examination and will only be possible under laboratory conditions.

With respect to *H. grandicornis*, the divers who collected the samples all commented on their dark coloration. Once an echinoid was overturned it was very easy to follow these organisms on the crustose coralline as they stood out particularly well. In addition, the average number of individuals of this species sheltering under the echinoid was very large. If these organisms were feeding under the echinoid, one would imagine that they are in competition for the same food resource as the echinoid. Thus, I would like to postulate that this species does not feed on the kelp trapped by the echinoid, but rather that it uses the echinoid for shelter during the day and feeds on algae at night. The dark coloration would render the species invisible at night on the crustose coralline surface.

The reason for this postulation is that, it is only just being realized how important meso-herbivores (invertebrates that are less than 2.5 mm in length (Barnes & Hugh, 1999)) are in maintaining algal communities. They perform several important functions such as removing epiphytes on macro algae and creating gaps in perennial turfs (Brawley and Fei, 1987). Duffy and Hay, (2000) found that when fish and amphipods are present in a tank then green algae is cropped to a fine turf and space was more rapidly dominated by larger macro algae. They also found that reds dominated when there are large numbers of amphipods, whereas browns dominated when fish are present. If impacts of fish and amphipods are normalized for their aggregate biomass then the effects of amphipods grazing are greater by 1 – 2 orders of magnitude. If the large number of *H. grandicornis* sheltering under the echinoids were feeding and they were consuming the same resources as the echinoid, if one normalized their aggregate biomass compared to the echinoids then the effects of their grazing should be greater. One would also imagine that the echinoid would suffer from the association of these invertebrates and that it would actively try to prevent organisms from sheltering beneath them.

Apart from providing more shelter across the whole reef, the echinoids could reduce predation on the organism associated with them, because of their spines providing a defense mechanism against predators of the other organisms. This was shown by Day (1998), when juvenile abalone survival in areas where echinoids had been removed was significantly reduced compared to areas where echinoids were present.

CONCLUSION

Even though the amphipod *Paramoera capensis* only occurred in significant numbers at one echinoid site (RRL) the fact that 65 % had a colour variation that matches the echinoid, implies that this amphipod gains protection from predators by being associated with subtidal echinoids with some individuals being cryptic. However, this relationship is not obligate as this amphipod was found in other habitats.

The echinoid *Parechinus angulosus* appears to have a dual habitat preference with juveniles less than 10 mm in diameter sheltering beneath adult conspecifics and juveniles greater than 10 mm in diameter sheltering in kelp holdfasts. This relationship will require further research to see if the results obtained are a true reflection of what is occurring.

The amphipod *H. grandicornis* is known to occur in habitats other than under echinoids. It is found in the intertidal habitat associated with *Patella* sp and has a commensal relationship with the *Patella* gaining a favorable microclimate when it is low tide. This study suggests that it has an important relationship with subtidal echinoids. The amphipod is a known grazer of macro-algae (Branch et al, 1990) and thus it is possible that the amphipod gets access to a food resource in the form of drift kelp which is trapped by the echinoid. If this is the case then the amphipod would also be gaining protection from predators by being associated with the echinoid as the amount of time it is exposed while foraging is minimal. This however, needs to be investigated further.

Day (1998), concluded that juvenile abalone benefit from their association with echinoids through protection from predators, an enhanced food supply and a consequent reduction in the amount of time that they spend exposed while feeding. Although this study did not confirm or refute Day's conclusions, it is possible that due to the nature of the statistical analysis done on the data that this relationship was missed. This relationship is an obligate one as concluded by Day. By running the two-way ANOVA it was hoped that rare or territorial associations would become identifiable however this was not the case with this species.

One important question that needs to be answered in future research is whether the echinoid *P. angulosus* is a drift trapper or a grazer. The reason this question needs to be addressed is that it has important impacts on commensal associations. If the echinoid is a grazer then small invertebrates could be ingested while it feeds. If the echinoid were a drift trapper then invertebrate commensals would have access to an additional food resource.

This project has left a number of options open for further study. These options include selecting a single species found to have a close relationship with the echinoid in the field (like *H. grandicornis*) and testing the preference for this relationship in the laboratory. The second option is to test the nutritional benefits (if there are any) obtained from living under the echinoids, be this in the form of trapped drift kelp or from faeces. This could be done by radioactive labeling of food and therefore of the faeces. The third option is to look and see

if the preference is for echinoids, echinoids and kelp, rocks or kelp. The fourth option is to look for territorial relationships which make the organisms associated with the echinoids seem rare. An example of this is to see whether the association between *Halitosis midae* and the echinoid is a territorial one or if it is a rare occurrence.

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REFERENCES

- Anderson, R. J.; Carrick, P.; Levitt, G. J.; & Share, A. 1997. Holdfasts of *Ecklonia maxima* provide refuges from grazing for recruitment of juvenile kelps. Marine ecology progress series. Vol. 159. pg 265 – 273.
- Barnes, R. S. K. & Hughes, R. N. 1999. An introduction to marine ecology. Blackwell science. Edinburgh. pp. 101 – 102
- Begon, M., Harper, J. L. & Townsend, C. R. 1990. Ecology: Individuals, Populations and Communities. 2nd Ed. Blackwell Scientific Publications. Cambridge.
- Branch, G. M. 1975. The ecology of *Patella* from the Cape Peninsular, South Africa. 5. Commensalism. Zoologica Africana. 10 (2): 133 – 162.
- Branch, G. M., Griffiths, C. L., Branch, M. L. & Beckley L. E. 1994. Two Oceans, a guide to the marine life of Southern Africa. David Phillip. Cape Town. pp. 360
- Brawley, S. H. & Fei, X. G. 1987. Studies of mesoherbivory in aquaria and an un-barricaded mariculture farm on the Chinese coast. *J. Phycol.* Vol. 23: 614 – 623
- Day, E. 1998. Ecological interactions between abalone (*Haliotis midae*) juveniles and echinoids (*Parechinus angulosus*) off the southwest coast of South Africa. Ph.D. Thesis. UCT.
- Day, J. H. 1974. A guide to the marine life of South African Shores. A. A. Balkema. Cape Town. 272pp.
- Duggins, D. O. 1983. Interspecific facilitation in a guild of marine benthic herbivores. *Oecologia.* 48: 157 – 163.
- Duffy, J. E. & Hay, M. E. 2000. Strong impacts of grazing amphipods on the organization of a benthic community. *Ecological monographs.* 70 (2). 237 – 263
- Fletcher, W. J. 1987. Interactions among subtidal Australian echinoids, gastropods and algae. Effects of experimental removals. *Ecological Monographs.* 57(1): 89 – 109.
- Griffiths, C. L. 1976. Guide to the benthic marine amphipods of Southern Africa. Trustees of the South African Museum. Cape Town. 106pp.
- Kensly, B. 1978. Guide to the Marine Isopods of Southern Africa. Trustees of the South African Museum. Cape Town. 173pp.
- Rodriguez, S. R. and Ojeda, F. P. 1993. Distribution patterns of *Tetrapyrgus niger* (echinodermata: Echinoidea) off the central Chilean coast. *Mar. Ecol. Prog. Ser.* 101: 157 – 162.

- SANCOR. 1996. Abalone (perlemoen) resource about to collapse. SANCOR newsletter: May – Aug. Pg. 8 – 11.
- Stobie, C. S. 1998. Amphipod commensalisms with marine invertebrates in the South Western Cape, South Africa. Zoology Honours Thesis. UCT. 32pp.
- Tarr, R. J. Q. 1989. Abalone. Pp. 62 – 69. In: Payne, A. I. L. & Crawford, R. J. M. (eds.). Oceans of Life off Southern Africa. Vlaeberg Publishers. Cape Town. 380pp.
- Tarr, R. J. Q., Williams, P. V. G. & Mackenzie, A. J. 1996. Abalone, echinoids and rock lobster: a possible ecological shift may affect traditional fisheries. S. Afr. Mar. Sci. 17: 319 – 323.
- Tegner, M. J. & Butler, R. A. 1985. Abalone seeding. In: Handbook of culture of abalone and other marine gastropods. K. Ö Hahn (ed.). CRC Press Inc. Boca Raton. Florida. Pg. 157 – 182.
- Tegner, M. J. & Dayton, P. K. 1977. Population structure, recruitment and mortality of two echinoids (*Strongylocentrotus franciscanus* and *S. purpuratus*) in a kelp forest. Mar. Ecol. Prog. Ser. 5: 255 – 268.
- Tegner, M. J. & Dayton, P. K. 1991. Echinoids, El Niño and the long-term stability of Southern California Kelp forest communities. Mar. Ecol. Prog. Ser. 77: 49 – 63.
- Tegner, M. J. & Levin, L. A. 1983. Spiny lobsters and sea urchins: analysis of a predator-prey interaction. J. Exp. Mar. Biol. Ecol. 73: 135 – 150.
- Vader, W. 1978. Associations between amphipods and echinoderms. Astarte. 11: 123 – 134.
- Zar, J. H. 1999. Biostatistical Analysis. 4th Ed. Prentice-Hall. New Jersey. 663pp.

APPENDIX

DATA COLLECTION ON DIVES

TRANSECTS

Need six 8 m transects at each site, in the form of a star.

Randomly drop down a bouy line and swim for 8 m in north direction, paying out a tape measure

Then swim along transect line and note for 5 cm on either side of the transect line the area under the transect line

Note habitat type falling directly under tape measure to nearest 5 cm

Include the area under a echinoid as echinoid habitat

Next transect is 60 degrees from the last the last transect

Habitats include

Shale

Sand

Gravel

Small rocks (longest side being 10 cm)

Flat rock

Vertical rock

Kelp holdfasts

Crevices (includes sheltered areas between adjoining rocks)

"Under rock" areas

Sponge

Corallines

Echinoids

Polychaete mats

SAMPLING

Use stratified random sampling in collection of echinoids

Need echinoids from flat (horizontal) exposed rock surfaces/ areas covered by corallines, if echinoid not on coralline take note of where it is

First sample site take note of depth and collect 100 echinoids on flat/horizontal surfaces

Following that after establishing the minimum number to be collected

Then need to take stratified random samples from the following habitats in each site

Echinoids

Sand

Holdfasts of *Ecklonia maxima*

Corallines

EQUIPMENT TO BE USED

Permit
2 x weights
2 x buoy lines 20 m long
2 x tape measures
Collecting bottles
Storage bottles
Formalin
Scrapers
Carry bags x 4
Writing paper
Pen
Cockie

Dive slats with following information marked on them

Transect one

Shale 5 + 10 + 5 ...
Sand
Gravel
Small rocks < 10 cm
Flat rock
Vertical rock
Kelp holdfasts
Crevices
"Under rock" areas
Sponge
Corallines
Echinoids
Polychaete mats

Transect two

Shale 5 + 10 + 5 ...
Sand
Gravel
Small rocks < 10 cm
Flat rock
Vertical rock
Kelp holdfasts
Crevices
"Under rock" areas
Sponge
Corallines
Echinoids
Polychaete mats

Etc.

LIST OF ALL SPECIES FOUND AT THE FOUR STUDY SITES.

Phylum: Nemertea

Phylum: Sipunculida
Golfingia capensis (Teusch.)

Phylum: Annelida
Class: Polychaeta
Arabella iricolor (Mont.)
Lepidonotus semitectus clava (Stimpson)
Nephtys sp.
Syllis variegata (Gr.)
Thelepus sp.

Phylum: Arthropoda
Class: Crustacea

Sub-class: Ostracoda
Order: Myodocopa
Order: Podocopa

Order: Isopoda
Sub-order: Valvifera
Family: Idoteidae
Paridotea (Stebbing)
Paridotea rubra (Barnard, 1914)

Sub-order: Anthuridae
Family: Paranthuridae
Panathura (Barnard)
Parathura punctata (Stimpson, 1855)

Sub-order: Flabellifera
Family: Sphaeromatidae
Group: Eubranchiatae
Dynamenella (Hansen)
Dynamenella ovalis (Barnard, 1914)

Group: Hemibranchiatae
Cymodoce (Leach)
Cymodoce uncinata (Stebbing, 1902)

Exosphaeroma (Stebbing)

Exosphaeroma planum (Barnard, 1914)

Parisocladus (Barnard)

Parisocladus perforatus (Edwards, 1840)

Sphaeramene (Barnard)

Sphaeramene polytylotos (Barnard, 1914)

Sub-order: Asellota

Family: Jaeropsidae

Jaeropsis (Koehler)

Jaeropsis stebbingi (Kensley, 1975)

Family: Janiridae

Notasellus (Pfeffer)

Notasellus capensis (Barnard, 1914)

Order: Amphipoda

Sub-order: Gammaridea

Family: Acanthonotozomatidae

Iphimedia gibba (ex *Cypsiphimedia gibba* (K. H. Barnard, 1955))

Family: Ampeliscidae

Ampeliscia brevicornis (Costa, 1853)

Family: Amphilochidae

Cyproidea ornata (Haswell, 1880)

Family: Ampithoidae

Cymadusa filosa (Savigny, 1818)

Family: Eusiridae

Paramoera (Miers, 1875)

Paramoera capensis (Dana, 1853)

Family: Gammaridae

Ceradocus rubromaculatus (Stimpson, 1855)

Maera inaequipes (Costa, 1851)

Family: Liljeborgiidae

Liljeborgia palmata (Griffiths, 1974)

Family: Lysianassidae

Amaryllis macrophthalma (Haswell, 1880)

Lysianassa ceratina (Walker, 1889)

Family: Ochlesidae

Ochlesis lenticulosus (K. H. Barnard, 1940)

Super Family Talitroidae

Family: Talitridae
Hyale grandicomis (Kröyer, 1974)

Family: Temnophliidae
Temnophlias capensis (K. H. Barnard, 1916)

Family: Caprellidae
Caprella danilevski (Czerniavski, 1868)
Caprella equilibra (Say, 1818)

Family: Phtisicidae
Chaka leoni (Griffiths, 1974)

Order: Tanaidacea
Sub-order: Dikonophora
Family: Tanaidae
Anatanais gracilis (Heller)

Sub-order: Cumacea
Cumacea sp.

Order: Leptostraca/ Phyllocarida
Nebalia capensis (Barnard, 1914)

Order: Mysidaceae
Mysidaceae sp.

Class: Decapoda
Order: Anomura
Diogenes sp

Order: Brachyura
Family: Grapsidae
Plagusia chabrus (Linnaeus)

Class: Arachnida
Order: Pycnogonida
Tanystylum brevipes (Hoek)

Phylum: Mollusca

Class: Amphineura
Order: Polyplacophora
Chiton tulipa (Barnard)

Class: Pelecypoda
Aulacomya ater (Molina)
Pinctada capensis (Sowerby)
Tellina gilchristi (Sowerby)
Venus verrucosa (Linnaeus)

Class: Gastropoda
Gastropod sp.
Haliotis midae (Linnaeus)
Dendrofissurella scutellum
Helcion pectunculus (Gm.)
Patella miniata miniata (Born)
Tricolia neritina (Dnkr.)
Turbo cidaris cidaris (Gm.)
Volvarina zonata
Burnupena sp.

Class: Opisthobranchia
Pleurobranchaea bubala

Phylum: Echinodermata
Class: Ophiuroidea
Amphipholis squamata (delle Chiaje)
Ophionereis dubia (Müll & Trosch.)

Class: Echinoidea
Parechinus angulosus (Leske)

Class: Holothuroidea
Pseudocnella insolens (ex Cucumaria (Théel))