



*The status of the regular sea urchins (*Echinoidea*) at Aldabra Atoll, Republic of Seychelles.*

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Introduction:

The role of sea urchins (Echinoidea) as agents of bio-erosion on reefs has been well-documented (Bak 1990; Bak 1994; Clark 1976; McClanahan and Shafir 1990). Bio-erosion results from a generalised feeding strategy (Barnes 1987) and mechanical abrasion (Bak 1990), increasing in magnitude with elevated sea urchin densities (Bak 1994). Much of the reef biota is grazed, including algae, detritus and corals. Mean carbonate rock processing rates of $1.9 \text{ g urchin}^{-1} \text{ d}^{-1}$ and $0.11 \text{ g urchin}^{-1} \text{ d}^{-1}$ have been reported for *Diadema savigni* and *Echinometra mathaei* respectively, and, at elevated densities, urchins can graze at levels equaling carbonate production on reefs (Bak 1990). Areas that have suffered severe coral bleaching and mortality may be rapidly overgrown by algae (Westmacott *et al.* 2000) and, consequently, extensively colonised by urchins. During feeding on the new algal growth, the urchins remove large portions of reef substrate (Downing and El-Zahr 1987). As a result of this increased pressure, reef structure and topographical complexity are reduced (McClanahan and Kurtis 1991) resulting in a depression in the rate of coral recruitment (Sammarco 1980). The situation can be further confounded if fishing pressure reduces the abundance of urchin predators, primarily species of Balistidae, but also including scavenging species of Lethrinidae (McClanahan 2000; McClanahan and Kurtis 1991; McClanahan and Shafir 1990).

The wide scale coral bleaching and mortality event of 1997/1998 affected the coral reefs of the western Indian Ocean, which has prompted numerous scientific studies within the Republic of Seychelles (Burnett *et al.* in prep; Engelhardt 2000; Engelhardt 2001; Robinson *et al.* 2001; Spencer *et al.* 2000; Teleki *et al.* 1999^a; Teleki *et al.* 1999^b; Turner *et al.* 2000). Many of these studies have been designed to determine the extent of coral mortality, but few have evaluated the pre-settlement, settlement and post-settlement parameters of the recruitment process. Engelhardt (2001) has initiated a long-term study

focusing on the inner granitic Seychelles Islands, which includes investigations of coral settlement conditions and post-settlement survivorship. Using the methodologies of Engelhardt (2001), our study examines Echinoderms as an important reef community group with the potential to affect post-settlement coral survivorship at Aldabra Atoll. Focusing on the quantification of urchin abundance, we develop predictions of their potential impacts upon post-settlement coral survivorship.

Methods:

During Phase II of the Aldabra Marine Programme (AMP) in February 2001, quantitative surveys of urchin abundance were conducted at the 11 permanent AMP coral and reef fish monitoring sites. Eight of the AMP sites are on the outer reef, one in a coral dominated channel, and two at coral dominated lagoon locations (Figures 1 and 2). A total of 25 urchin survey dives were made. For logistical reasons all surveys were made using SCUBA during daylight hours, although some qualitative observations were made during night dives. The presence of the coral predator *Acanthaster planci* (Crown of Thorns) was also investigated at these sites, and qualitative observations of urchins and *A. planci* were also made at a number of adjacent locations. Prior to the surveys, training in the survey methodology was conducted and was then practiced by the team members to minimise observer error.

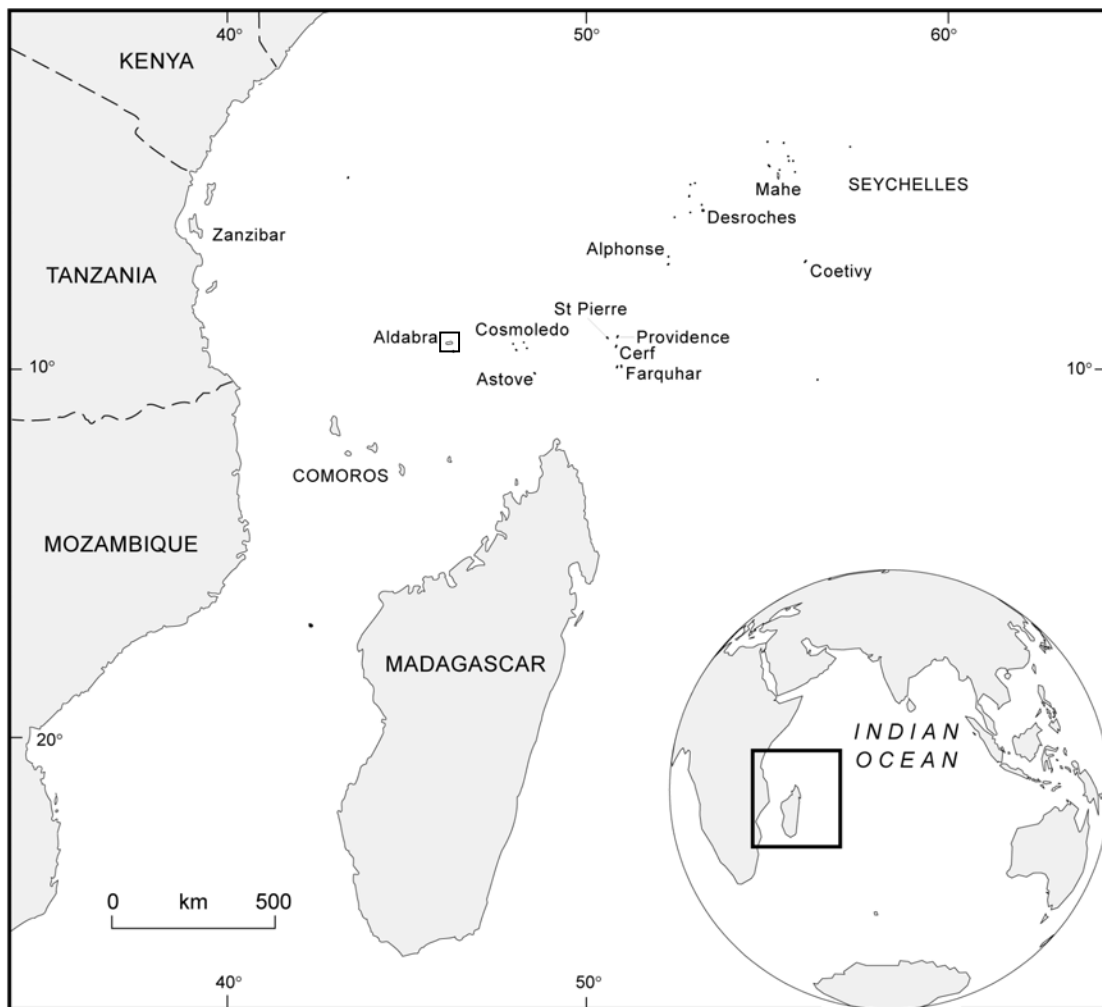


Figure 1: Geographical location of Aldabra Atoll, Republic of Seychelles.

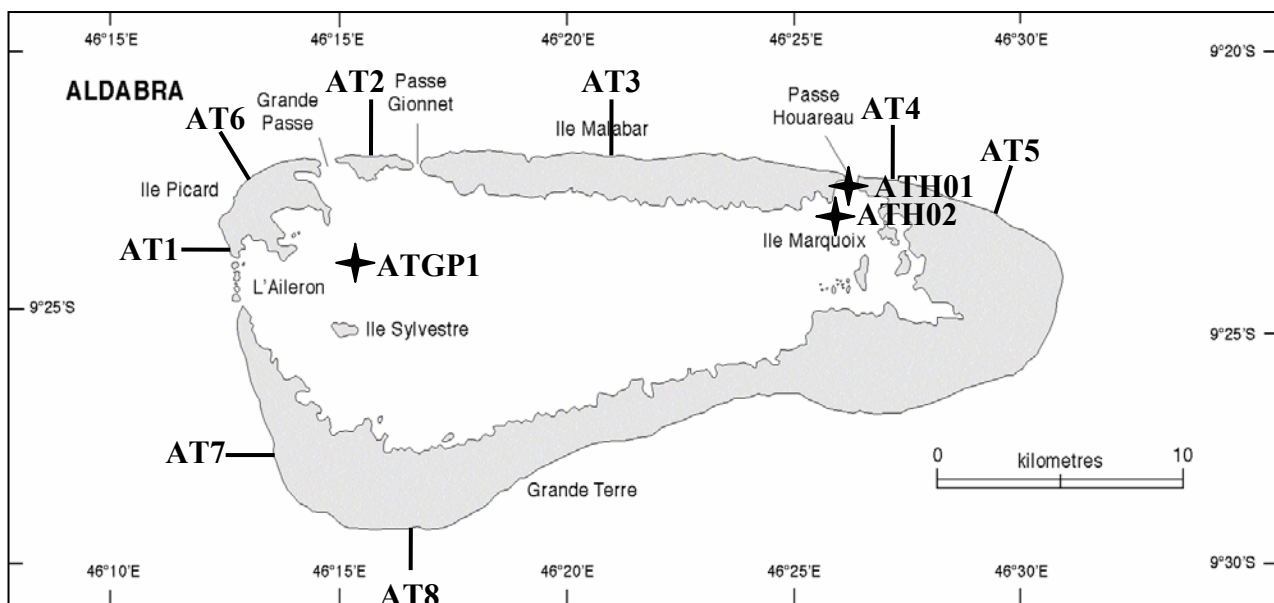


Figure 2: Aldabra Atoll with the 11 permanent Aldabra Marine Programme monitoring sites for coral and reef fish studies.

For comparative purposes, a similar method to that employed by Engelhardt (2001) was utilised for the urchin surveys, the primary difference being a 50% reduction in the survey area, at each site, owing to time and personnel constraints. At each AMP survey site, two replicate 125m² (50m x 2.5m) belt transects were randomly established at an oblique angle to the reef slope. Each observer individually examined one 2.5m belt transect per site. At all outer reef sites, transects were placed as close as possible within the 2m to 15m depth range, outlined in Englehardt (2001), although transect depths did vary between sites owing to the heterogeneous reef profiles (Table 1). Typically, the start depths were greater than those surveyed by Engelhardt (2001) in the inner granitic Seychelles Islands studies. At the shallow lagoon and channel sites, transects were surveyed to a maximum depth of 9.9m. The complete descriptions of the permanent AMP survey sites can be obtained from Stobart *et al.* (2001); Teleki *et al.* (1999^b); Teleki (2000).

Following the method of Engelhardt (2001), the three ‘target’ urchins, *Diadema setosum*, *D. savigni* and *E. mathaei*, were selected for this study, although ‘non-target’ urchins were recorded if observed within the survey area. Although most species were identified *in-situ*, specimens were collected, photographed, and sent to the British Natural History Museum, with accompanying habitat descriptions, for taxonomic verifications.

Table 1: Urchin transects starting and ending depths (see Figure 2).

AMP Site #	AT 1	AT 2	AT 3	AT 4	AT 5	AT 6	AT 7	AT 8	AT H01	AT H02	AT GP1
T1 Start Depth (m)	6	7.2	7.4	5.7	4.8	7.3	6.4	8.3	1.0	2.3	2.0
T1 End Depth (m)	12.4	18	17.8	19.3	10.3	24.3	17.3	15.6	1.0	3.3	2.0
T2 Start Depth (m)	8.9	6	6	7.4	7.5	5.6	6.7	9.6	1.0	9.3	2.0
T2 End Depth (m)	16.5	15	13.8	17.7	16.5	9.0	16	15	1.5	9.9	2.0

Mean species counts (n=2) per 125m² were calculated (± 1 Standard Deviation, SD), per site, for ‘target’ and ‘non-target’ urchin species. In addition, pooled urchin taxa density counts were compiled per site. Black spined urchin (BSU) index values were assigned, as an indicator of the potential threat to post-settlement coral survivorship, using pooled ‘target’ urchin counts (*D. setosum*, *D. savigni* and *E. mathaei*). BSU index values were based upon Engelhardt (2001; Table 2). An index value of ‘3’ (47.5 individuals per 125m²) indicates the maximum sustainable density of urchins (Engelhardt 2001). The additional index classification category of ‘bio-eroding’ was developed to encompass the

three ‘target’ species as well as *Echinostrephus molaris*, a bio-erosive species (Bak 1994) not found around the inner granitic Seychelles Islands. The observed urchin species and densities are described, and reasons are suggested for between site species variability. Results are compared with historical studies of Aldabra Atoll (Sloan *et al.* 1979; Clark 1984), and with contemporary inner granitic Seychelles Island surveys (Engelhardt 2001). All urchin data are presented as counts per 125m².

Table 2: Black spined urchin (BSU) Index Value (adapted from Engelhardt 2001).

BSU Index value	BSU Density rating	Criteria for visual assessment of respective density categories
1	Very low BSU abundance	Mean of ≤ 12.5 BSU per 125m ²
2	Low BSU abundance	Mean of 13-30 BSU per 125m ²
3	Moderate BSU abundance	Mean of 30.5-47.5 BSU per 125m ²
4	High BSU abundance	Mean of 48-62.5 BSU per 125m ²
5	Very high BSU abundance	Mean of >62.5 BSU per 125m ²

Coral recruit survey data presented in this report are from the eight outer reef survey sites at Aldabra Atoll (Stobart *et al.* 2001), and from four sites (Ste. Anne, Cerf, Cousin and Curieuse; Figure 3) around the inner granitic Seychelles Islands (Burnett *et al.* in prep). These data offer an insight into pre-settlement, settlement and post-settlement conditions. The AMP surveys in February 2001 collected coral recruit data from up to nine randomly positioned 4m x 1m quadrats, at each of the 6m, 10m, and 20m survey depths. A maximum width of 5cm was used as the upper limit for defining recruits (Engelhardt 2001). These criteria are based on *in-situ* coral growth rate observations of Wallace (1985), Wallace *et al.* (1986) and van Moorsel (1988). Fast growing *Acropora* corals have been shown to reach a maximum size, two years after settlement, of between 2cm and 5cm (Wallace 1985; Wallace 1999). The coral recruit data from the three survey depths are pooled for this report. Coral recruit data from the inner granitic Seychelles Islands (Burnett *et al.* in prep) were collected using twenty randomly positioned 4m x 1m quadrats at each of the four sites (Figure 3), with recruits defined by a maximum width of 10cm (Turner 2000; Sheppard *et al.* 2000). All coral recruit data are presented as counts per m².

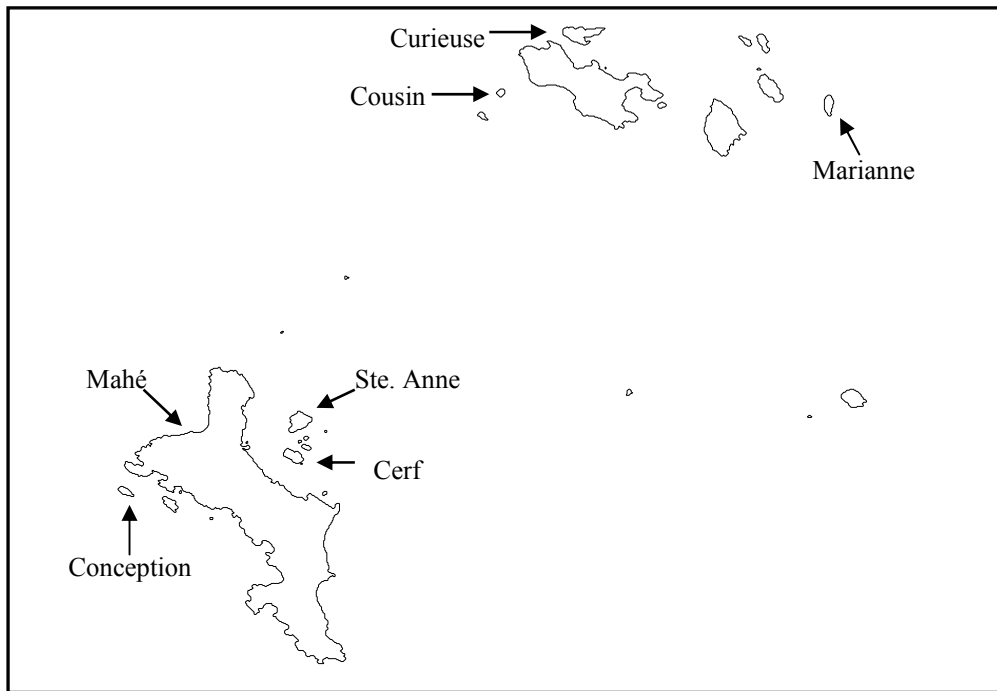


Figure 3: Inner Granitic Seychelles Islands, with the four coral monitoring sites: Ste. Anne, Cerf, Cousin and Curieuse Islands (Burnett *et al.* in prep).

The abundance of species of Balistidae and Lethrinidae, found at the eight survey sites on the outer reef at Aldabra Atoll during AMP Phase II (Stobart *et al.* 2001), are used in this report to speculate on the role of these fishes as urchin predators. The AMP surveys collected fish density data along a 50m x 4m transect at 10m depth, and along a 25m x 4m transect at 20m depth, at each site. The fish density data at the two survey depths are combined for this report as the urchin surveys were made across both depth ranges. In addition, balistid and lethrinid abundance data (S. Jennings, The Centre for Environment, Fisheries and Aquaculture Science, CEFAS, unpublished data), collected at four sites from the Ste. Anne Marine Park (Figure 3), inner granitic Seychelles Islands, are used for comparisons. These data were collected along sixteen replicate 50m x 5m transects at each site. The balistid and lethrinid data from Aldabra Atoll and Ste. Anne Marine Park sites are presented as counts per 100m².

Results:

A total of five urchin species, representing three families, were quantitatively sampled; Echinometridae – *E. molaris* and *E. mathaei*, Diadematidae – *D. setosum* and *Astropyga radiata*, and Toxopneustidae - *Tripneustes gratilla*. An additional two urchin species,

from two of the same families, were observed outside of the transects, either by the sampling team, or by other members of the AMP; *Echinothrix calamaris* (Diadematadae) and the pencil urchin, *Heterocentrotus trigonarius* (Echinometridae). Dr. Andrew Smith of the British Natural History Museum, London, verified the identifications of *E. molaris*, *D. setosum*, and *E. mathaei*. Full descriptions of these species can be found in Sloan *et al.* (1979) and Clark (1984). All of these urchin species were observed within the coral reef habitat, or among the corals in the lagoon and channels.

The urchin survey transects conducted at Aldabra Atoll (February 2001) had starting and ending depths that ranged from 4.8m to 24.3m, which reasonably duplicated the 2m to 15m depth range outlined in Engelhardt (2001). These transects estimated urchin densities that varied dramatically between sites (Table 3; Figures 4 and 5). The burrowing, non-target, *E. molaris* was notably the most abundant, reaching a maximum site density of 251.5 ± 33.2 SD per 125m^2 at site AT8, with a minimum density of zero at site ATGP1. *E. molaris* were mostly small, with a test diameter of approximately 1cm, but some achieved a test diameter of 3cm. *E. molaris* was estimated to be the most abundant urchin at 10 of the 11 sites, site ATGP1 being the anomaly. It was also the most widely distributed. The target urchins *D. setosum* and *E. mathaei* were observed in small densities; *D. setosum* had a maximum site density of 4.0 ± 2.8 SD per 125m^2 at site AT8, and *E. mathaei* a maximum site density of 1 ± 1.4 SD per 125m^2 at site ATH02. All of the *D. setosum* were juveniles with an estimated maximum test diameter of 2cm. *E. mathaei* had a maximum test diameter of approximately 3cm. The remaining target species, *D. savigni*, was not observed within quantitative surveys, although it was observed during other survey dives. *D. setosum* was found at five survey sites, and *E. mathaei* at four sites, and these were the only target urchins quantitatively recorded. Other non-target species, *A. radiata* and *T. gratilla*, were observed, but each at only 1 site (AT5 and AT6, respectively).

Site AT8 showed the highest pooled urchin density per 125m^2 (256 ± 36.8 SD), followed by sites AT7 (56 ± 38.2 SD), AT5 (49.5 ± 36.1 SD) and AT6 (30 ± 19.8 SD), with *E. molaris* by far the dominant species. *E. molaris* also dominated the total urchin counts of sites AT1-AT4, although with much reduced densities. The channel site of ATH01 exhibited the highest abundance of urchins of the three sites in the channel and lagoon, followed by the lagoon sites ATH02 and ATGP1. Again, *E. molaris* was dominant,

although it was not noted at site ATGP1. Site ATH01 also exhibited a higher urchin abundance (consisting solely of *E. molaris*) than any of sites AT1-AT4.

Table 3: Mean species counts per 125m² (± 1 SD) and pooled urchin counts per 125m² (± 1 SD) for each quantitative AMP survey site (see Figure 2).

Site	<i>D. setosum</i>	<i>E. molaris</i>	<i>E. mathaei</i>	<i>A. radiata</i>	<i>T. Gratilla</i>	All Species
AT1	1.0 \pm 1.4	9.0 \pm 1.4	0.5 \pm 0.7	0.0	0.0	10.5 \pm 2.1
AT2	0.0	7.0 \pm 4.2	0.0	0.0	0.0	7 \pm 4.2
AT3	1.0 \pm 1.4	14.5 \pm 12.0	0.0	0.0	0.0	15.5 \pm 13.4
AT4	1.0 \pm 1.4	11.5 \pm 6.3	0.0	0.0	0.0	12.5 \pm 7.8
AT5	0.0	49.0 \pm 35.3	0.0	0.5 \pm 0.7	0.0	49.5 \pm 36.1
AT6	0.0	29.5 \pm 20.5	0.0	0.0	0.5 \pm 0.7	30 \pm 19.8
AT7	2.5 \pm 3.5	53.5 \pm 41.7	0.0	0.0	0.0	56 \pm 38.2
AT8	4.0 \pm 2.8	251.5 \pm 33.2	0.5 \pm 0.7	0.0	0.0	256 \pm 36.8
ATH01	0.0	23.0 \pm 15.5	0.0	0.0	0.0	23 \pm 15.6
ATH02	0.0	3.5 \pm 0.7	1 \pm 1.4	0.0	0.0	4.5 \pm 0.7
ATGP1	0.0	0.0	0.5 \pm 0.7	0.0	0.0	0.5 \pm 0.7

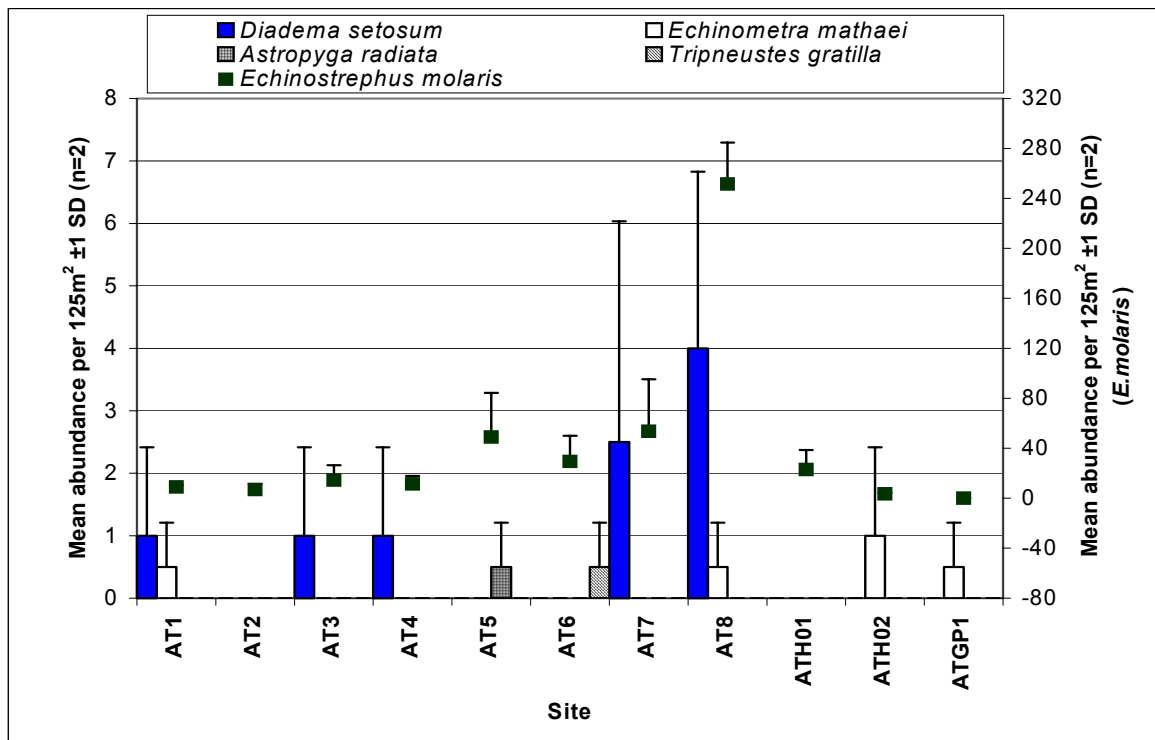


Figure 4: Mean counts (n=2, + 1 SD), per AMP survey site (see Figure 2), of the urchin species quantitatively sampled at Aldabra Atoll (y-axis represents *D. setosum*, *A. radiata*, *E. mathaei* and *T. gratilla*; z-axis represents *E. molaris* only).

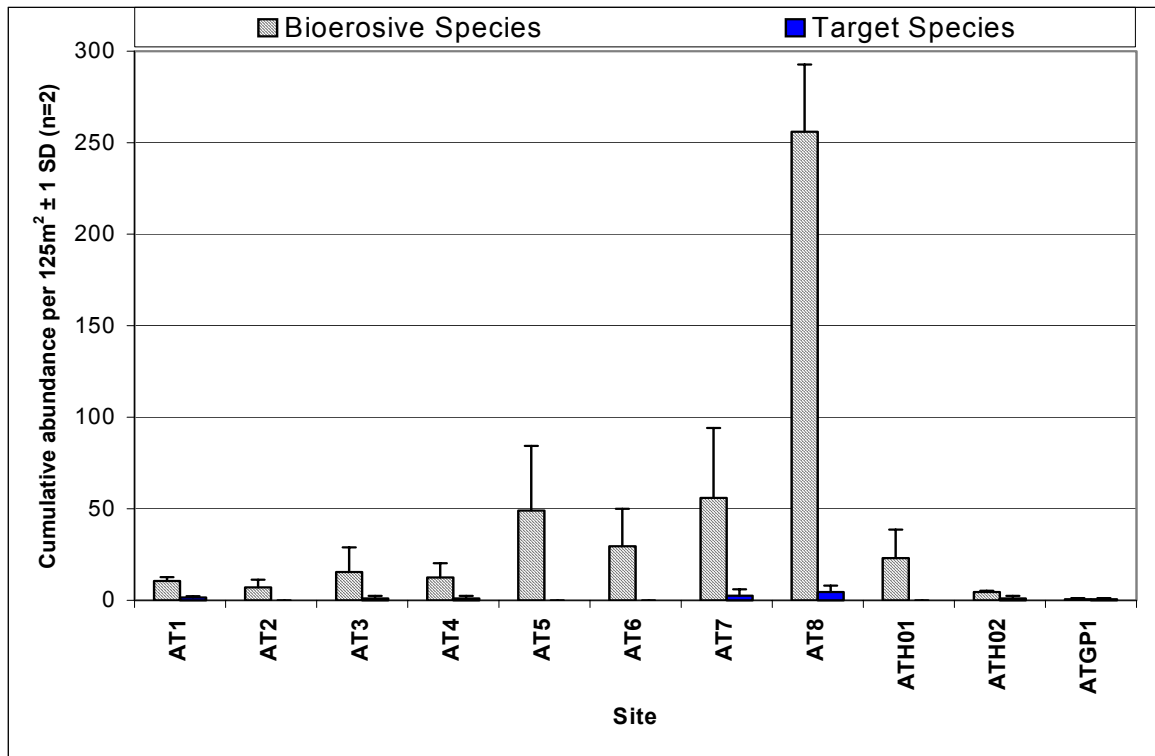


Figure 5: Cumulative counts (n=2, + 1 SD), per AMP survey site (see Figure 2), of the target and bio-eroding urchin species quantitatively sampled at Aldabra Atoll.

Following the method of Engelhardt (2001), each site at Aldabra Atoll was given a black spined urchin (BSU) index value (Figure 6). When focusing solely on the target urchins (*E. mathaei*, *D. setosum* and *D. savigni*) the BSU index value ‘1’ was never exceeded at Aldabra Atoll (Figure 6). Sites AT2, AT5, AT6 and ATH01 (36.4% of sites) did not register a BSU index value, while remaining sites were given a value of 1 (63.6% of sites). In contrast, ‘bio-erosive’ urchin counts (*E. mathaei*, *D. setosum*, *D. savigni* and *E. molaris*) showed 27.3% of sites (AT5, AT7 and AT8) to be above the BSU threshold index value of ‘3’, with BSU index values of ‘4’, ‘4’ and ‘5’ respectively. All remaining sites (72.7%) showed BSU index values of ‘1’ or ‘2’.

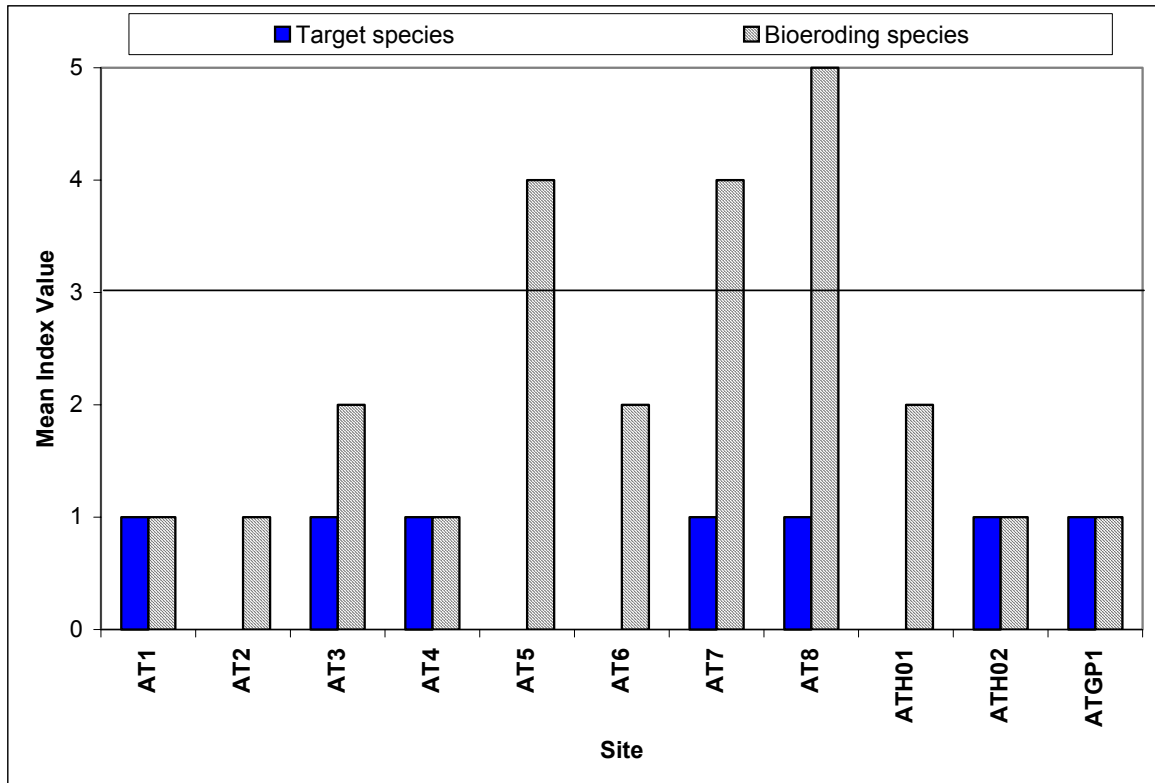


Figure 6: Black spined urchin (BSU) index values for target (*E. mathaei*, *D. setosum* and *D. savigni*) and bio-eroding (*E. mathaei*, *D. setosum*, *D. savigni* and *E. molaris*) species.

The obligate coral predator, *A. planci*, was not observed in the surveys of any of the AMP permanent transects. However, *A. planci* was noted during qualitative investigations. Two *A. planci* were observed adjacent to Passe Gionnet (Figure 2), both in the shallows of the inner lagoon (Souter, pers. comm., 2001). These were juveniles of approximately 15cm diameter. One *A. planci* was observed in Passe Houareau (in the channel) at 2m depth (Stobart, pers. comm., 2001). No other *A. planci* were recorded during AMP phase II.

In support of the discussion, coral recruit and fish data from Aldabra Atoll (Stobart *et al.* 2001) and the inner granitic Seychelles Islands (Burnett *et al.* in prep; S. Jennings, The Centre for Environment, Fisheries and Aquaculture Science, CEFAS, unpublished data) are presented. Although sampling methodologies, timing, and inevitably habitats, differed between the surveys conducted at Aldabra Atoll and the inner granitic Seychelles Islands, important qualitative comparisons can be still obtained from these data.

Discussion:

The 1997/1998 warm water event resulted in the most severe and widespread bleaching episode on record (Wilkinson 1998), and has prompted increased scientific interest in coral reef recovery processes. With urchins believed to play a leading role with respect to the success of coral recolonisation (Sammarco 1980, 1982), assessment of their abundance is essential if the threats posed to the recovery of corals are to be quantified reliably. The reef complex of Aldabra Atoll, which exhibited pronounced bleaching induced mortality (Teleki *et al.* 1999^b), offers significant value as a study site for investigating reef recovery processes in the absence of major anthropogenic disturbances.

Prior to this survey, nothing was known of the urchin population densities of Aldabra Atoll. Although there have been previous studies by Sloan *et al.* (1979) and by Clark (1984), they did not quantify urchin abundance, however, they provide an excellent checklist of information (Table 4). A total of twenty regular urchin species, representing seven families, were reported. For the species observed during the AMP Phase II survey, there are some notable omissions, as only seven species (three families) were recorded (Table 4). However, this can be readily attributed to the AMP surveys focussing exclusively on the coral reef habitats of Aldabra Atoll. Sloan *et al.* (1979) and Clark (1984) reported sampling in a variety of habitats, including seagrass beds, sand flats, coral reefs, rocky shores and intertidal rock platforms. When solely considering the coral reef habitat, our urchin observations are well represented compared to those of Sloan *et al.* (1979) and Clark (1984).

Spatially, urchin densities indicated some interesting patterns at Aldabra Atoll. Site AT8, which showed by far the largest density of *E. molaris* (almost 5 times greater than any other site), is situated on the exposed southern coast of the atoll which has a strong-current environment driven by the south equatorial current, and SE trade winds (May to October). Surface currents around the perimeter of Aldabra Atoll were recorded at approaching 0.5 metres per second during July 1987 (Anon. 1987). These strong-current environments are preferred by *E. molaris* (Barnes 1987). Sites AT7 and AT5 possess a SW and NE aspect, respectively, and are consequently afforded some protection from the SE trade winds. Correspondingly, these sites exhibited lower densities of *E. molaris* when compared with the fully exposed site, AT8. The sites on the sheltered, northern side, of the atoll (AT1,

AT2, AT3, AT4 and AT6) exhibited lower densities again. The northern side of the atoll is protected from the SE trade winds, and presumably a lower current velocity limits the abundance of *E. molaris*. Surprisingly, even though site AT2 is situated in close proximity to Grande Passe (where current velocity is high owing to the diurnal flushing of the lagoon), it had the lowest abundance of *E. molaris* of all the outer reef sites. It is possible that the current velocity at AT2 is too strong to permit successful settlement of urchin larvae. Sites surveyed within the strong-current, but shallow, lagoon environment (ATH02 and ATGP1) were characterised by much smaller densities of *E. molaris* compared to sites on the outer reef, and in the channel (ATH01). However, both lagoon sites are occasionally exposed during spring low tides, a potentially inhibitive factor for urchin survival. Other urchin species did not reveal any strong geographical preferences, although *D. setosum* was recorded to reach its largest density (4.0 ± 2.8 SD per 125m²), at site AT8.

Table 4: Regular Echinoidea of Aldabra Atoll from 1979, 1984, and 2001 surveys. (The AMP Phase II list combines qualitative (*) and quantitative observations. ‘A’ signifies presence only on Aldabra Atoll).

Sloan <i>et al.</i> (1979) ¹ , and Clark (1984) ²	Aldabra Marine Programme (2001)
Cidaridae	
<i>Eucidaris metularia</i> (Lamarck, 1816) ^{1,2}	---
<i>Phyllacanthus imperialis</i> (Lamarck, 1816) ^{1,2}	---
<i>Prionocidaris baculosa</i> (Lamarck, 1816) ^{1,2}	---
<i>Prionocidaris verticillata</i> (Lamarck, 1816) ^{1,2}	---
Diadematidae	
<i>Astropyga radiata</i> (Leske, 1778) ^{1,2}	<i>Astropyga radiata</i> (Leske, 1778)
<i>Diadema savigni</i> (Michelin, 1845) ^{1,2}	---
<i>Diadema setosum</i> (Leske, 1778) ¹	<i>Diadema setosum</i> (Leske, 1778)
<i>Echinothrix calamaris</i> (Pallas, 1774) ^{1,2}	<i>Echinothrix calamaris</i> (Pallas, 1774)*
<i>Echinothrix diadema</i> (Linnaeus, 1758) ²	---
Stomechinidae	
<i>Stomopneustes variolaris</i> (Lamarck, 1816) ^{1,2}	---
Temnopleuridae	
<i>Salmaciella dussumieri</i> (L. Agassiz) ²	---
<i>Salmacis bicolor</i> (L. Agassiz) ²	---
<i>Temnotrema siamense</i> (Mortensen) ²	---
Toxopneustidae	
<i>Tripneustes gratilla</i> (Linnaeus, 1758) ^{1,2}	<i>Tripneustes gratilla</i> (Linnaeus, 1758)
<i>Toxopneustes pileolus</i> (Lamarck, 1816) ^{1,2}	---
Parasaleniiidae	
<i>Parasalenia gratiosa</i> (A. Agassiz, 1863) ^{1,2} (A)	---
Echinometridae	
<i>Colobocentrotus atratus</i> (Linnaeus, 1758) ^{1,2}	---
<i>Echinometra mathaei</i> (de Blauville, 1825) ^{1,2}	<i>Echinometra mathaei</i> (de Blauville, 1825)
<i>Echinostrephus molaris</i> (de Blauville, 1825) ^{1,2} (A)	<i>Echinostrephus molaris</i> (de Blauville, 1825)
<i>Heterocentrotus trigonarius</i> (Lamarck, 1816) ^{1,2}	<i>Heterocentrotus trigonarius</i> (Lamarck, 1816)*

Although we have not quantified the pre-settlement and settlement conditions at Aldabra Atoll, some information does exist which we can consider in relation to the urchin's role with regard to post-settlement coral survivorship. With the inner granitic Seychelles Islands believed to have suffered one of the greater mass mortalities of corals, when compared with other Indian Ocean reefs (Turner *et al.* 2000), it can be assumed that the reefs of Aldabra Atoll may have better recovery prospects than those of the inner granitic Seychelles Islands. Teleki and Spencer (2000) made this observation for other islands in southern Seychelles. It can, therefore, be assumed that there would be greater larval availability from the surviving colonies at Aldabra Atoll and, if settlement conditions are favourable, an associated level of coral recruitment. Teleki *et al.* (1999^b) report that the death of large numbers of corals during the 1997/1998 warming event had not led to an explosion of macroalgae. Encrusting coralline algae was evident upon the surfaces of dead corals at Aldabra Atoll (Teleki *et al.* 1999^b), a crucial factor for successful substrate consolidation, and in favour of coral settlement. Coral recruit surveys conducted at Aldabra Atoll (Stobart *et al.* 2001) and the inner granitic Seychelles Islands (Burnett *et al.* in prep) indicate differing settlement levels (Table 5; Figures 7 and 8). Hard coral recruit counts at Aldabra Atoll averaged 6.0 per m² (Stobart *et al.* 2001), compared with an average of 1.2 per m² around the inner granitic Seychelles Islands (Burnett *et al.* in prep). These differences in recruitment rates are even more striking when considering the inner granitic Seychelles Island surveys used a coral recruit size criteria twice that of the Aldabra Atoll surveys (10cm and 5cm, respectively). From this evidence, it appears that the coral recovery process at Aldabra Atoll is well under way, in comparison to the inner granitic Seychelles Islands. Aldabra Atoll appears to provide more suitable pre-settlement and settlement conditions, owing to a comparatively abundant larval supply and a substrate suited to successful larval settlement. The continued success of the coral recovery process at Aldabra Atoll, therefore, very much depends upon the status of post-settlement conditions.

Table 5: Mean coral recruit counts per m² (± 1 SD) at Aldabra Atoll (AMP Phase II, Stobart *et al.* 2001) and the inner granitic Seychelles Islands (Burnett *et al.* in prep).

Recruits (≤ 5 cm)	Site	Recruits (≤ 10 cm)
4.6 \pm 1.2	AT1	-
4.2 \pm 1.3	AT2	-
7.6 \pm 1.2	AT3	-
6.9 \pm 2.5	AT4	-
5.1 \pm 4.0	AT5	-
2.6 \pm 0.9	AT6	-
7.8 \pm 1.2	AT7	-
9.1 \pm 4.9	AT8	-
-	Ste. Anne	1.1
-	Cerf	1.3
-	Curieuse	1.5
-	Cousin	0.8
6.0 \pm 2.2	TOTAL	1.2 \pm 0.3

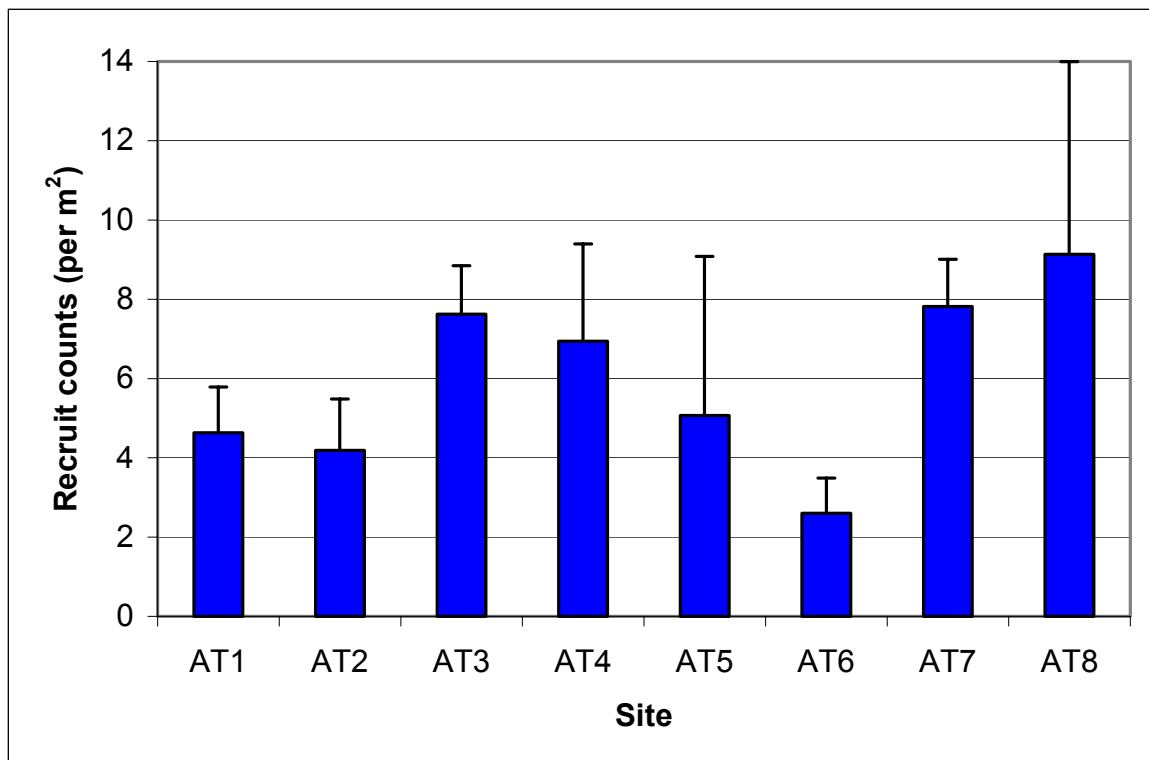


Figure 7: Mean coral recruit counts per m² (n \leq 108, + 1 SD) at Aldabra Atoll.

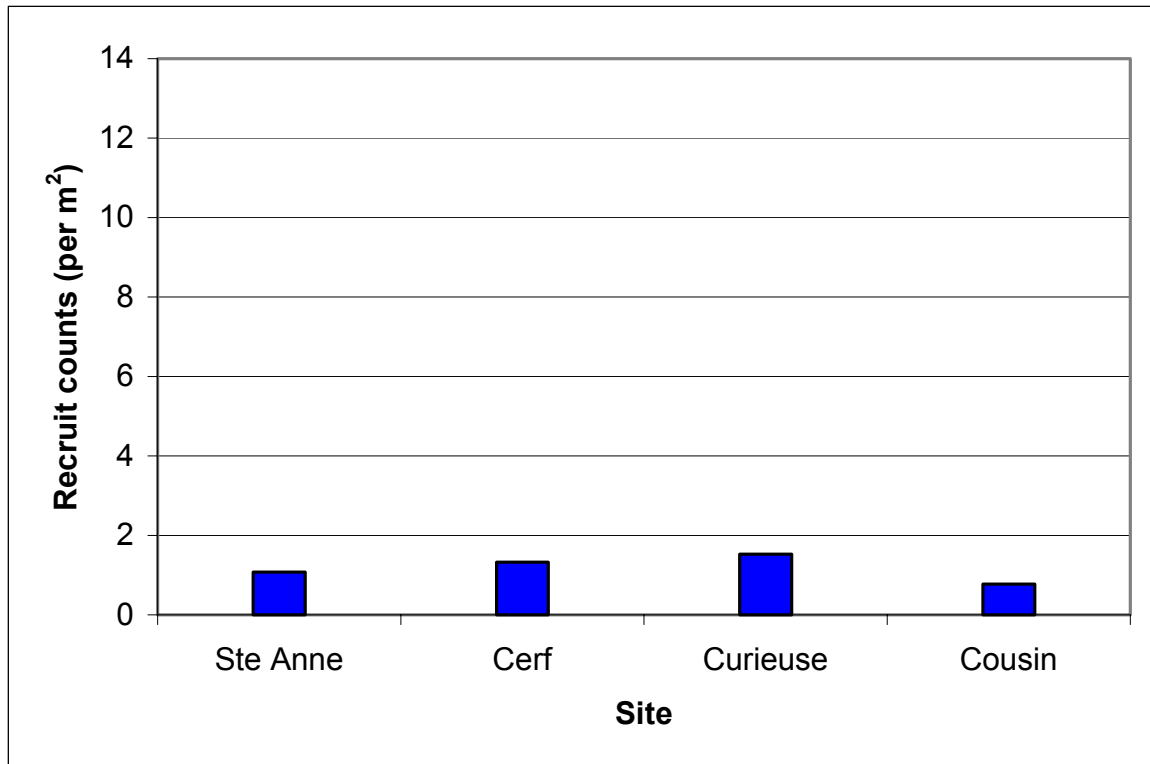


Figure 8: Mean coral recruit counts per m² (n=80) from the inner granitic Seychelles Islands.

Fortunately, the post-settlement conditions also appear favourable for coral recovery. Aldabra Atoll possesses a small abundance of target urchins, unlike the inner granitic Seychelles Islands (Engelhardt 2001). Reaching a maximum density of 4.5 target urchins per 125 m² at Aldabra Atoll, compared to a maximum 250 per 125m² around the inner granitic Seychelles Islands, it is suggested the impact of target urchins on coral recruit survivorship at Aldabra Atoll is negligible. This is reinforced by the evaluation that the BSU index value of ‘3’ (the critical threshold) is never exceeded for the target species on Aldabra Atoll, and by the comparative abundance of coral recruits. Conversely, 13 of the 22 sites (59.1%) surveyed by Engelhardt (2001) show a BSU index value of ‘3’ or above; 7 of the 22 sites (31.8%) were given the BSU rating of ‘5’. Engelhardt (2001) also reported a significant increase in urchin density at 77% of the 22 sites surveyed in 2000, over values obtained in 1999. Including the moderately bio-erosive *E. molaris* into the Aldabra Atoll density counts (maximum of 256 ‘bio-eroders’ per 125m²) raises 3 sites above the critical density threshold (27.3% of sites). However, this does not appear to have a detrimental effect on coral recruitment as two of these sites (AT8 and AT7) have the highest number of coral recruits of the sites surveyed, and the remaining site (AT5) also has a healthy number

of coral recruits. *E. molaris* primarily feeds on endolithic and encrusting algae from the wall of its burrow, as well as on algal fragments and other organic debris that are washed into the burrow (Barnes 1987). Therefore, it is suggested that the presence of *E. molaris* does not have a strong influence on the post-settlement survival of coral recruits. Conversely, Engelhardt (2001) suggests the coral reefs of the inner granitic Seychelles Islands are hosting excessively high densities of urchins (*E. mathaei* and *Diadema* spp.) with the potential for serious ecological effects. Engelhardt (2001) sighted sea urchin grazing, and scarring, on a variety of newly settled hard corals. Such scarring was not observed at Aldabra Atoll during our surveys. Engelhardt (2001) reported the lowest urchin densities around the eastern and western margins of the survey area (Marianne Island and Conception Island, respectively; see Figure 3). Densities increased in magnitude towards the central region, in close proximity to well-developed human settlements and activities, particularly around Mahé.

Observations of *A. planci*, being very limited, suggest no present threat to the corals of Aldabra Atoll. Similarly, Engelhardt (2001) only recorded one *A. planci* throughout the 22 inner granitic Seychelles Island survey sites.

It is well known that several species of resident reef fish play a crucial role with respect to urchin population control (McClanahan 2000; McClanahan and Kurtis 1991; McClanahan and Shafir 1990), with some being described as keystone species (McClanahan 2000; Paine 1966). McClanahan *et al.* (1989, 1990, 1991 and 2000) have shown that removal of urchin predators (primarily balistids, but including scavenging lethrinids) can result in increased densities of urchins and the competitive exclusion of herbivorous fish. Balistids, being agonistic and territorial, are often the first to suffer through fishing as they are generally the initial species to take bait or to enter a trap (McClanahan 2000). Marine Protected Areas surveyed by McClanahan *et al.* (1989 and 1991) showed a high abundance of urchin predators correlated with a small population of urchins. The reverse was true for unprotected areas. We suggest that the marine protected status (i.e., it is an UNESCO World Heritage Site) and isolated locality of Aldabra Atoll is a major contributing factor controlling the urchin population. Balistid and lethrinid data gathered from Aldabra Atoll (Stobart *et al.* 2001) and the inner granitic Seychelles Islands (S. Jennings, The Centre for Environment, Fisheries and Aquaculture Science, CEFAS, unpublished data) provide value

to our discussion (Table 6; Figures 9 and 10). Unlike the inner granitic Seychelles Islands, where fishing has been a long-standing tradition, Aldabra Atoll boasts a strong population of balistids and lethrinids, even when compared with the Ste. Anne Marine Park (where fish poaching is an issue, Jennings *et al.* 1995). Balistid density at the eight AMP outer reef survey sites at Aldabra Atoll (Stobart *et al.* 2001) was 3.8 per 100m², while lethrinid density was 2.7 per 100m². Assuming fish abundance within Ste. Anne Marine Park have remained similar since 1998, the data reveal a balistid density of zero per 100m², and a lethrinid density of 0.3 per 100m² (S. Jennings, The Centre for Environment, Fisheries and Aquaculture Science, CEFAS, unpublished data). Even though there are inherent differences in reef habitat between Aldabra Atoll and the inner granitic Seychelles Islands, we suggest the urchins of Aldabra Atoll, with little to no fishing pressure, are actively consumed by these important day time predators.

Table 6: Mean balistid and lethrinid counts per 100m² (\pm 1 SD) at Aldabra Atoll (AMP Phase II, Stobart *et al.* 2001) and Ste. Anne Marine Park (S. Jennings, The Centre for Environment, Fisheries and Aquaculture Science, CEFAS, unpublished data).

Aldabra Atoll			Ste. Anne Marine Park		
Site	Balistidae	Lethrinidae	Site	Balistidae	Lethrinidae
AT1	0.5 \pm 0.7	4.0 \pm 2.9	S1	0.0	0.2 \pm 0.3
AT2	3.5 \pm 2.1	2.0 \pm 1.4	S2	0.0	0.5 \pm 0.6
AT3	0.5 \pm 0.7	0.3 \pm 0.4	S3	0.0	0.1 \pm 0.2
AT4	0.8 \pm 0.4	6.3 \pm 2.5	S4	0.0	0.2 \pm 0.3
AT5	4.3 \pm 0.4	1.5 \pm 2.1			
AT6	3.8 \pm 0.4	1.7 \pm 0.5			
AT7	3.5 \pm 0.7	4.0 \pm 5.0			
AT8	13.3 \pm 18.8	2.0 \pm 2.8			
TOTAL	3.8 \pm 4.2	2.7 \pm 1.9	TOTAL	0.0	0.3 \pm 0.2

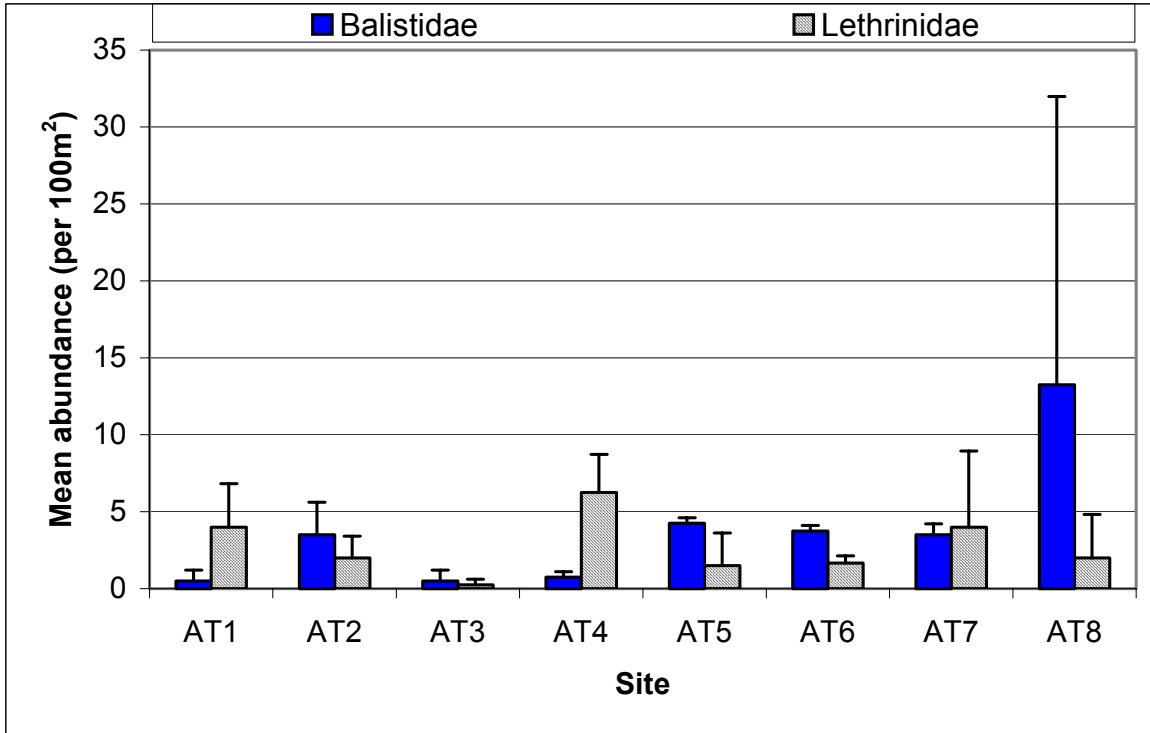


Figure 9: Mean balistid and lethrinid counts per 100m² (n=2, + 1 SD) at Aldabra Atoll.

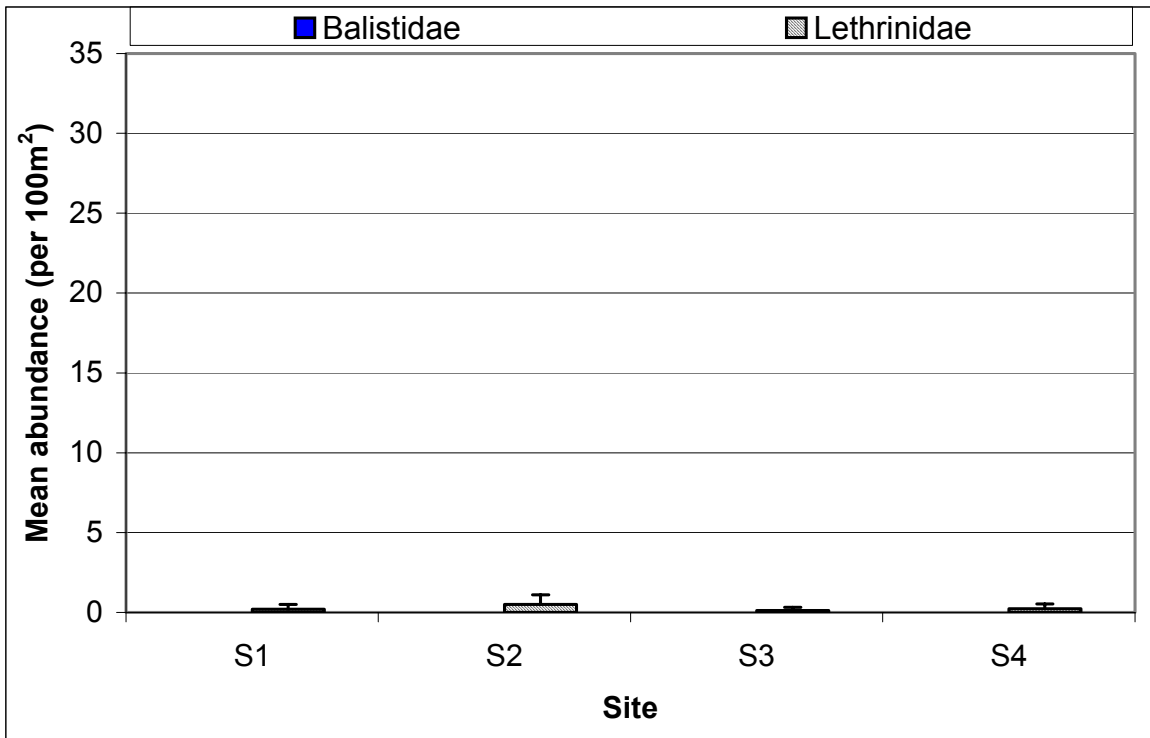


Figure 10: Mean balistid and lethrinid counts per 100m² (n=16, + 1 SD) at Ste. Anne Marine Park.

We conclude that Aldabra Atoll is better equipped for coral regeneration than the inner granitic Seychelles Islands, due in part to suffering less coral mortality (Turner *et al.* 2000). With relatively small urchin densities, it is proposed that Aldabra Atoll has a larger potential to support the post-settlement survival of coral recruits than the inner granitic Seychelles Islands. Our study suggests that the low urchin densities at Aldabra Atoll are primarily attributable to the control exerted by an abundance of fish predators. Fortunately for Aldabra Atoll, its protected status, lack of development, and isolation provide substantial benefits to the ‘keystone’ urchin predators. However, we must be aware that a decline of coral reef habitat complexity and concomitant reef fish abundance (Sebens 1991; Turner *et al.* 1999; Williams 1991), as a result of the 1997/1998 coral bleaching event, is still possible. Such a decline, albeit lagged, may have the potential to disrupt the delicate balance between urchin densities and coral regeneration.

Recommendations:

- It is recommended that a long-term urchin-monitoring programme be established, to include other coral grazers/predators (e.g. *Drupella cornus*), on the reef habitats of Aldabra Atoll. Given the urchins’ important role in the coral reef community, continued population monitoring is vital for our understanding of reef regeneration dynamics, and to provide early warnings of potential population outbreaks. Ideally, these studies should be performed in parallel with AMP permanent coral and fish surveys (20m, 10m, and 6m depth contours).
- It is recommended that experimental studies of urchin grazing rates be conducted with a focus on post-settlement coral recruit survivorship. Through the quantification of urchin grazing rates, estimates of sustainable urchin populations for reef regeneration should be obtained for Aldabra Atoll and similar coral reefs. This study should also encompass the important role of fishes in controlling urchin populations.
- It is recommended that the skills developed by the urchin sampling team members be used for additional surveys, to complement the research conducted through the AMP, and to expand to new survey areas.

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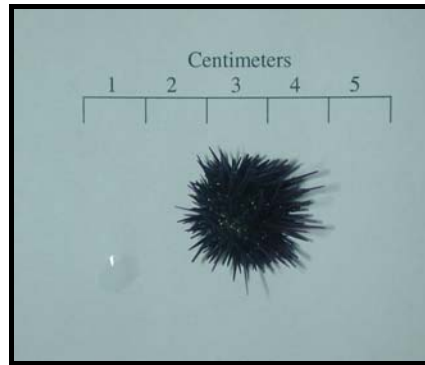
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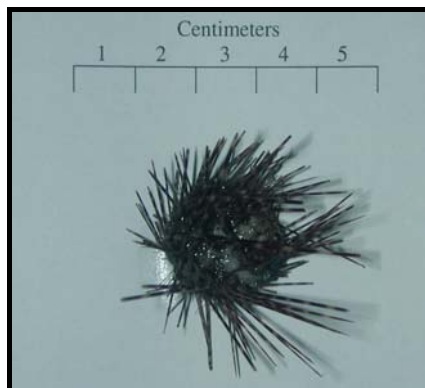
Appendices:

Bio-erosive species encountered during AMP (2001).

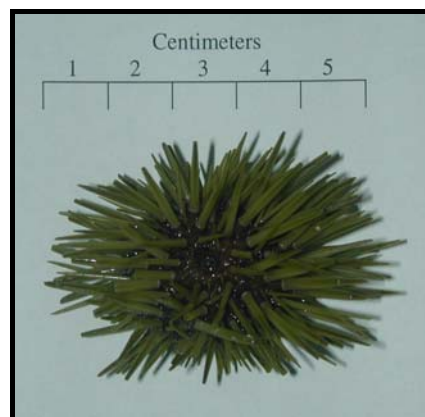
Echinostrephus molaris



Diadema setosum (juvenile)



Echinometra mathaei



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