Anne Grete Rostad

Coral recruitment success on a protected and a fished reef off Zanzibar, Tanzania

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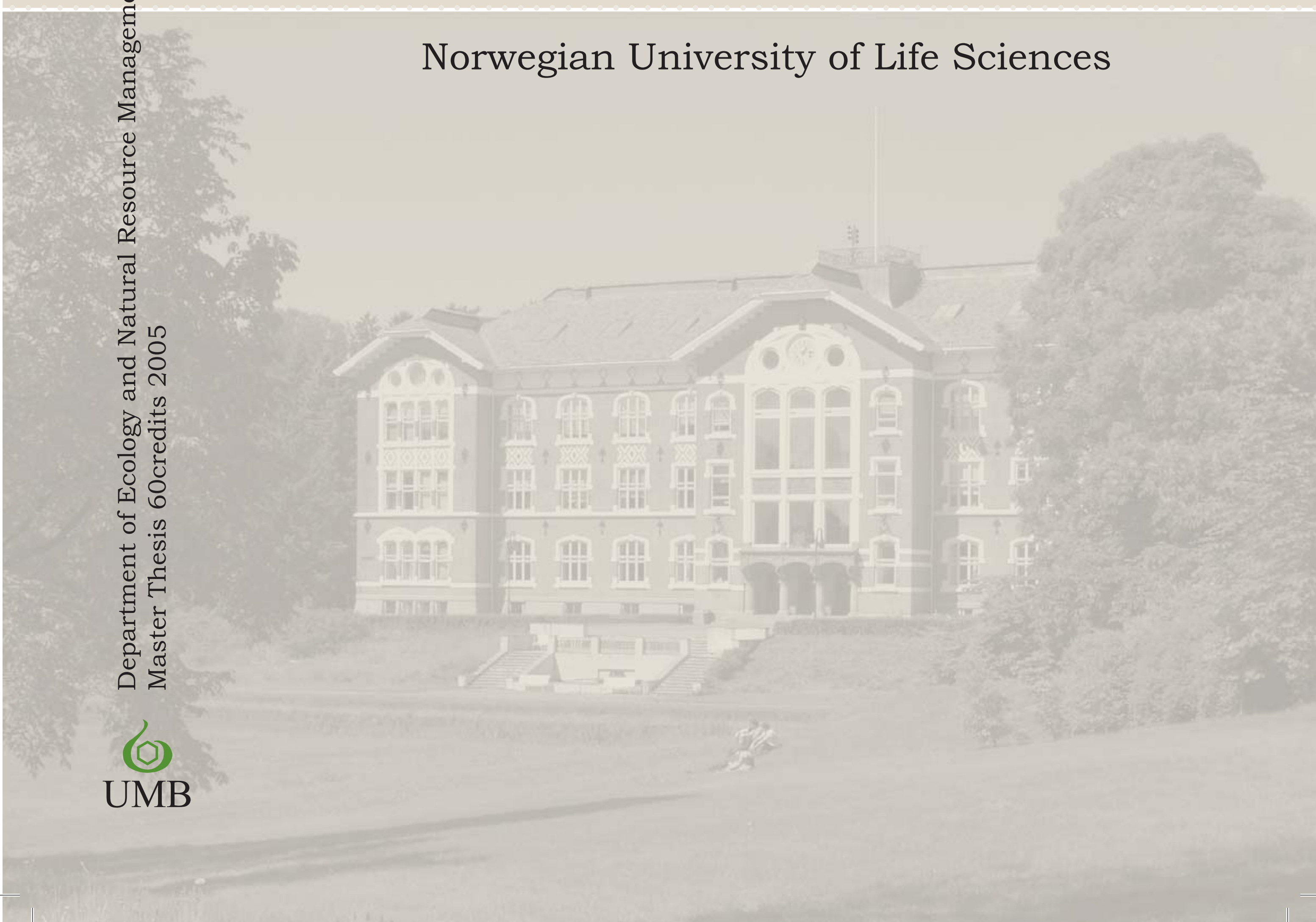

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Ås, Norge, 15.mai 2005

Anne Grete Rostad

Sammendrag

Dette studiet ser på forskjell i korall rekruttering (korall kolonier under 10 cm) mellom fredet og ikke-fredet korallrev utenfor Zanzibar, Tanzania. Jeg har sammenlignet to sesonger (sør-østlig monsun- juni/juli og nordøstlig monsun- desember/januar), med seks måneders mellomrom. Rekruttene ble identifisert til familier og størrelsen på rekruttene ble målt. Etter seks måneder ble de samme rekruttene gjenfunnet og målt på nytt. Slik kunne jeg finne ut hvor mange som hadde overlevd de seks månedene, hvor mye de hadde vokst, samt hvor mange nye rekrutter som hadde etablert seg.

Dette studiet viser overraskende at overlevelsesratene var like blant rekruttene mellom det fredede området og det ikke-fredede området. Grunnen kan være høyere konkurranse for plass, men også høyere predasjon fra fisk, i det fredede området. Resultatene indikerer også at dødeligheten blant korallene er større på det freda revet.

A.G. Rostad

Coral recruitment success in a protected and a fished reef off Zanzibar, Tanzania.

Abstract This study compares success in coral recruitment (coral colonies under 10 cm) in a protected reef and an adjacent unprotected reef off the Zanzibar coast, Tanzania. I documented the number of survivors for different coral families and compared the reefs during two seasons (southeast monsoon and northeast monsoon). I measured the recruits' sizes and growth rates. Sightings of the crown-of-thorns-starfish (*Acanthaster planci*) and substrate coverage by Corallimorpharia were recorded. The results indicate that there were no significant differences in recruitment rates between the protected and unprotected reefs. Thus coral recruitment is not necessarily more successful in protected reefs, perhaps due to increased predation by fishes and competition for space. The results also suggest that recruit mortality was higher in the protected reef.

Keywords Marine protected areas · Fished reefs · Coral recruitment · Recruit survival · Recruit growth

Introduction

Coral reefs are particularly vulnerable to certain forms of disturbance, such as increases in sea temperature above normal ranges (Hoeg-Guldberg and Smith 1989; Loya et al. 2001; Loch et al. 2002; Loch et al. 2004), sedimentation (Gittings et al. 1988; Rogers 1990; Meesters et al. 1992; Barnes and Lough 1999; Nugues and Roberts 2003; Munday 2004), increased dissolved nutrient levels due to pollution (McCook 1999; Edmunds et al. 2001; Nordemar et al. 2003), lowered salinity due to freshwater influxes (McCook 1999), physical damage by destructive fishing methods or anchoring damage (Lirman and Miller 2003), and increased turbidity caused by mining activities (Barnes and Lough 1999; Guzman et al. 2003). Many of these disturbances are caused or exacerbated by human activities.

In protected marine areas, however, many of these disturbances may be controlled or even absent. After protective measures have come into effect, positive changes in the biodiversity have been detected (Halpern and Warner 2002).

In a reef system, many competitors and predators interact with the coral colonies. The Corallimorpharia (Cnidaria, Anthozoa) compete with corals for space, and have a competitive advantage during periods of disturbance, and especially if accompanied by nutrient increase (Langmead 1999; Muhando et al. 2002; Muhando and Kuguru 2002; Kuguru et al. 2004). The crown-of-thorns starfish (*Acanthaster planci*) is a predator on corals (Bellwood et al. 2004).

Resilience to disturbances differs among corals. Poritidae are well adapted to stresses such as sedimentation, whereas Pocilloporidae are more vulnerable, and Acroporidae are intermediate (Meesters et al. 1992; McClanahan and Obura 1997). Finely branched corals, such as Pocilloporidae and Acroporidae are particularly susceptible to increased sea temperature (Marshall and Baird 2000). High mortality was observed among branching corals during bleaching episodes, such as the El Niño event in 1998 (Loch et al. 2002; Loch et al. 2004). However, the massive and encrusting corals, such as Poritidae, are more tolerant to increased sea temperatures and are often the dominating coral family after disturbance (Loya et al. 2001). The resilience of a coral reef is important for the maintenance of the reef system. Lack of resilience among the corals could lead to loss of fragile species or a phase shift towards an algae-dominated reef (McClanahan 2002; Nyström and Folke 2001; Nordemar et al. 2003).

Recruit dispersal is important to maintain the adult population of coral colonies (Harii and Kayanne 2003). Degradation of adult colonies can affect the recruitment success and the ability of the coral colonies to recover after a severe disturbance (Hughes et al. 1999; Hughes et al. 2000). Thus, encrusting and massive corals could enjoy an advantage during recovery after major disturbances. These corals may become more abundant in the subsequent period, and even come to dominate in frequently disturbed reefs. High resilience among corals in reef systems will probably withstand changes in the relative abundance of branching corals than towards encrusting and massive corals. Fast-growing species, such as Acroporidae and Pocilloporidae, may re-inhabit their original areas shortly after disturbances (Marshall and Baird 2000) and prevent such phase shifts (Nyström and Folke 2001; Nordemar et al. 2003).

Corals in protected areas may have a poor adaptation to disturbance, but their increased biodiversity and protection from physical disturbances could allow a better recovery from disturbance than unprotected areas, which are subjected to frequent disturbance (McClanahan et al. 2002; West and Salm 2003).

The aim of this study was to examine the differences in coral recruitment between a protected area and an unprotected area by examining (1) the numbers of coral recruits, (2) the survival rates after six months, (3) the composition of coral families, (4) the growth rates of the coral recruits and correlate with (5) the occurrence a competitor, Corallimorpharia and a predator, the Crown-of-thorns starfish.

Materials and methods

Study sites

The study was conducted at two small island reefs off the coast of Zanzibar town, Tanzania. The reefs were Chumbe, which is 13 km south of Zanzibar town, and Bawe, which is 7 km west of Zanzibar town. Chumbe is a marine sanctuary where fishing is forbidden and only non-extractive research is allowed. Snorkelling is conducted under the supervision of park rangers. Boats are not allowed inside the boundaries, except those belonging to the marine park. Bawe is an important fishing ground as well as a tourist destination and research area, with no specific regulations governing the use of resources. Bawe is a frequently fished area and is regularly visited by tourists. However, Bawe experiences less sedimentation than Chumbe (Muhando 2003; Persson and Tryman 2003).

The studied reefs were in shallow water, the deepest parts being 8 m at low tide. The shallow parts were less than 1 m at low tide and some were even exposed during spring low tides. The reef in Bawe is patchy, whereas the reef in Chumbe is continuous, and has higher coral cover (Mohammed et al. 2002).

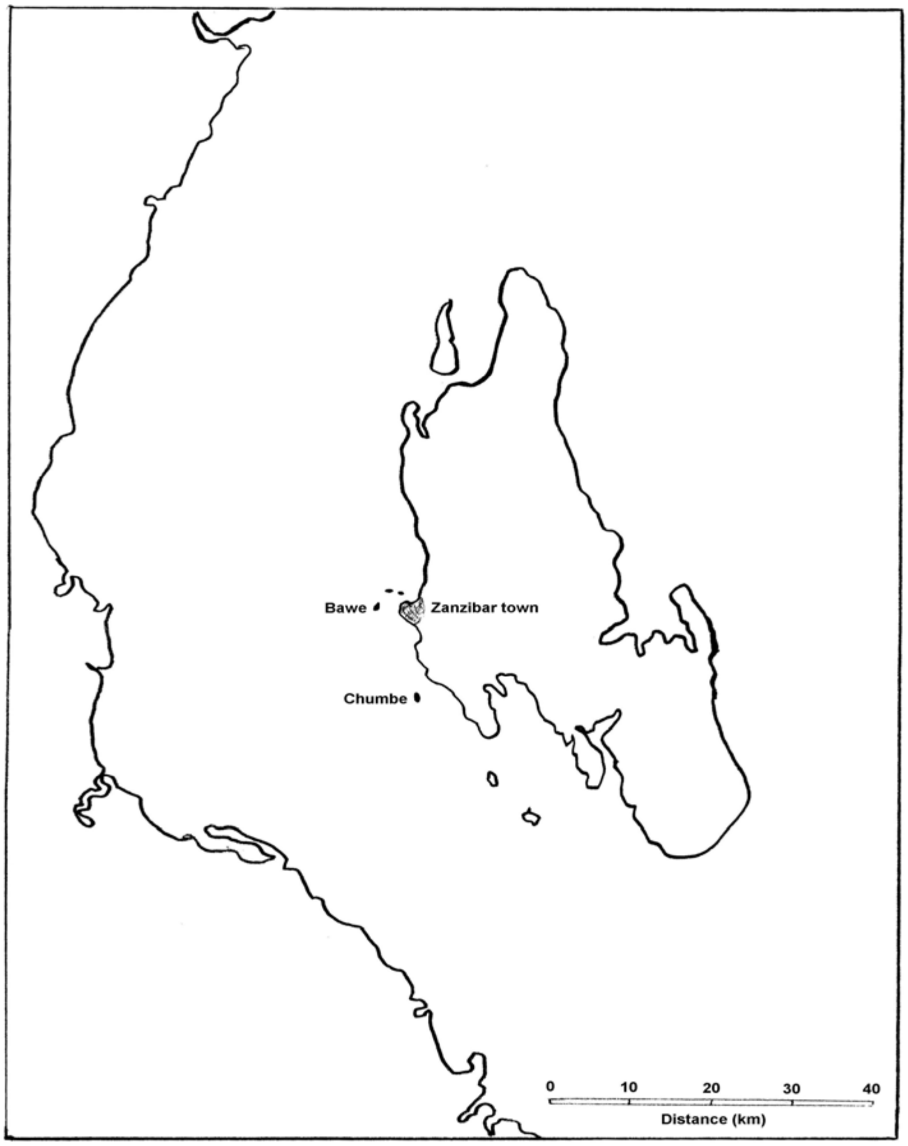

Fig.1 Map showing the location of the study sites off Zanzibar, Tanzania

Recruit count and measurements

Recruit counts and measurements were conducted during two seasons, the southeast monsoon (SEM, June- July 2004) and the northeast monsoon (NEM, December- January 2005). The measurements were conducted at two depths of 2 and 5 m during mid-tide to investigate whether there were differences between these two depths at each of the reefs. Ten quadrats ($1m^2$) were sampled randomly at each of these depths, constituting a total of 20 quadrats per reef. Quadrats completely filled with sand or fully covered by live coral cover were excluded and a new area was chosen. At both reefs, permanent markers were made defining the position of each quadrat to facilitate re-sampling during the next visit.

Coral recruits were identified in the field and specimens photographed. The recruitment canopy cover was determined by measuring the maximum length and width perpendicular to the length. The empty spaces in the canopy of branching corals were not taken into consideration. Recruits were classified as corals <10 cm in both length and width. During the second field period, new measurements were made on the same individual coral recruits. New recruits inside the same quadrat were counted and measured, and their taxonomic group was recorded. Recruits not found in the second season were classified as dead.

The coral recruits where divided into four families:

- Poritidae (*Porites lobata, P. annae, P. rus, P. nigrescens, P. cylindrica, P. lutea*),
- Acroporidae (*Acropora* spp. *Montipora* spp. *Astreopora* spp.),
- Pocilloporidae (*Pocillopora, Stylophora* and *Seriatopora*)
- "Others" (other hard coral genera).

The formula used to estimate the canopy size of the coral recruits was:

Recruit Size (S): $[(L/2)^* (\pi)]^*(W/2)^*(\pi)]$ (Muhando 2003)

Where L=length and W=width

The formula used to estimate the growth rate of the coral recruits was:

$$\text{Growth rate (G)} = \frac{[(S2)] - [(S1)]}{\text{Time (T)}}$$

Where S1= Recruit size SEM, S2= Recruit size NEM and T= 6 months

Benthic cover

Benthic cover was estimated visually during the SEM (June-July 2004) by determining the percentage cover of live hard coral, dead coral, rubble and sand inside each quadrat.

Corallimorpharia cover and Crown-of-thorns starfish

Corallimorpharia density was estimated visually as a percentage inside each quadrat. *A. planci* individuals were recorded whenever sighted.

Statistical analyses

Unpaired student t-tests were used to test for differences between samples at 2 and 5 meters depths, differences in number of recruits between Chumbe and Bawe in the two seasons, as well as for taxonomic differences between the reefs. Paired t-test was used to test for differences in the mean number of recruits on the same reef in the two seasons. A one-way ANOVA was used to test for differences in the taxonomic composition within the two different reefs during the two seasons. A one-way ANOVA also was used to compare the survival rate of different coral families within the two reefs. When comparing for differences among the same coral families in the different reefs t-test were used. The t-test was used to detect differences in size and growth among the recruits of the same coral families.

Non-parametric data were tested with Kruskal-Wallis and Mann Whitney tests. The percentage survival of the different coral families was found by dividing the number of corals with the total number found in the SEM in the two different reefs, and then tested with a Kruskal Wallis test. Corallimorpharia abundance in the two reefs in the two seasons was tested with a Mann Whitney test.

A level of significance chosen was $p=0.05$ for all analyses and two-tailed tests were used throughout. After every ANOVA test, a Tukey's post-hoc test was conducted to find pair-wise differences for parametric data and Dunn's post-hoc test for non-parametric data.

Results

Combined recruitment

The number of recruits did not differ significantly between 2 and 5 meters depth in Bawe (unpaired t-test, $t= 0.61$, $p=0.55$, $df=18$) or Chumbe (unpaired t-test, $t= 2.0$, $p=0.06$, $df= 18$). Therefore data from both depths were combined for further analyses.

In the SEM there was a difference in total density of coral recruits between Chumbe and Bawe ($t=2.4$, $p=0.02$, $df=38$). Recruitment was significantly higher in Chumbe ($mean=7.8\pm0.73$) than at Bawe ($mean=5.3\pm0.73$). No difference between these reefs was found during the NEM between Chumbe ($mean=6.0\pm0.77$) and Bawe ($mean=6.6\pm0.71$, $t=0.57$, $p=0.57$, $df=38$).

Recruitment success showed no seasonal difference in Bawe ($t=1.9$, $p=0.07$, $df=19$), and therefore does not have higher recruitment success in one or the other season. However, Chumbe showed a seasonal difference in recruitment success ($t=2.7$, $p=0.01$, $df=19$). Chumbe had higher recruit density during the SEM ($mean=7.8\pm0.73$) compared to the NEM ($mean=6.0\pm0.71$). Chumbe therefore had a higher recruitment activity during the SEM

(Fig.2). However it is important to note that the data from NEM included recently settled recruits, which were not present during the SEM.

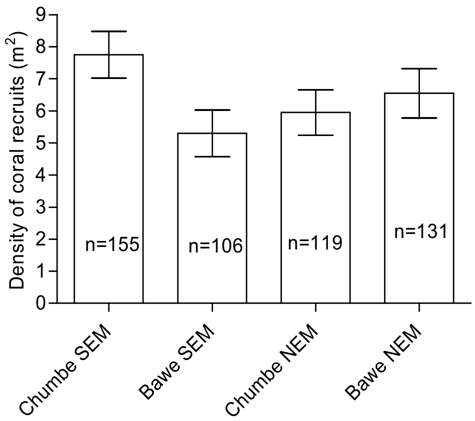

Fig. 2 Mean seasonal density of coral recruits found in Chumbe (protected reef) and Bawe (unprotected reef), Zanzibar, during two seasons, with bars showing standard error of the mean

Differences among coral families

In the SEM no difference in recruitment densities was found among the coral families at Chumbe (one-way ANOVA, F=0.67, p=0.57). In Bawe however, there was a significant difference (one-way ANOVA, F=10, p<0.0001): there was a low density of Acroporidae and "Others" compared to Pocilloporidae and Poritidae (Tukey's post-hoc test, Table1). Also during the NEM Bawe showed a significant difference among the coral families (one-way ANOVA, F= 3.9, p=0.012), in contrast to Chumbe (one-way ANOVA, F=0.44, p=0.73). Recruit density for the Acroporidae was lower at Bawe (Fig.3). However, recruit density of the "Others" did not differ significantly from Pocilloporidae and Poritidae during the NEM (Fig. 4, Table1)

Table 1 Summary of ANOVA and Tukey's results comparing recruit density at the two reefs at the two seasons near Zaznibar. Lines underneath means join those families which are not significantly different at p=0.05, but break between those who are significantly different

Season	Reef	ANOVA	Tukey's post-hoc test				
SEM	Bawe	p<0.0001	Poc	Por		Acro	Others
		mean	3	1.9		0.2	0.2
SEM	Chumbe	p=0.57	Acro	Poc	Por	Others	
		mean	2.2	2.2	2	1.5	
NEM	Bawe	p=0.012	Por	Poc	Others	Acro	
		mean	2.6	2.4	1.3	0.25	
NEM	Chumbe	p=0.73	Acro	Por	Others	Poc	
		mean	1.7	1.7	1.4	1.3	

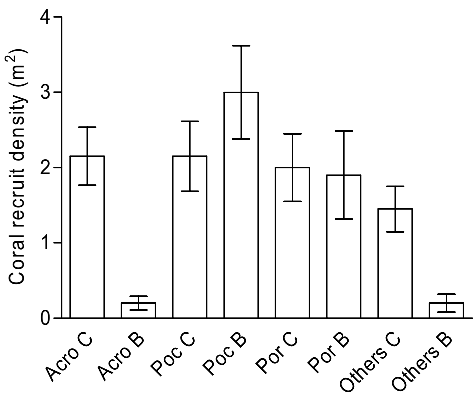

Fig. 3 Mean seasonal recruit density of corals at Chumbe (C) and Bawe (B), Zanzibar for Acroporidae (Acro), Pocilloporidae (Poc), Poritidae (Por) during southeast monsoon (SEM) 2004, with bars showing standard error of the means

In the SEM there was a significant difference in coral families' composition between Bawe and Chumbe. The Acroporidae (t=4.9, p<0.0001, df=38) and "Others" (t=3.8, p=0.0004, df=38) had a higher recruit density in Chumbe (Acroporidae mean=2.15±0.39, "Others"mean= 1.45±0.3) than what was found in Bawe (Acroporidae mean=0.2±0.09, "Others"mean= 0.2±0.1, Fig.3).

Also during the NEM there was a difference in recruit density among coral families between Chumbe and Bawe. The Acroporidae had higher recruit density in Chumbe (mean=1.7±0.3) compared to Bawe (mean=0.25±0.1, t=4.3, p<0.0001, df=38, Fig. 4). However, the "Others" in Bawe (SEM mean=0.2±0.1, NEM mean=1.3±0.8) during the NEM changed from having a significant difference to no significant difference compared to Chumbe (SEM mean= 1.45±, NEM mean=1.4±, Table 2, Fig.3 and Fig.4).

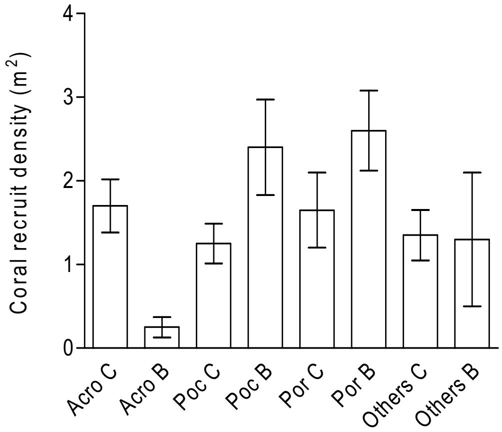

Fig.4 Mean density of coral recruits in Chumbe (C) and Bawe (B), Zanzibar for Acroporidae (Acro), Pocilloporidae (Poc), Poritidae (Por) in northeast monsoon (NEM) 2004/2005, with bars showing standard error of the means

Table 2 Main results from t-test in recruit difference between Bawe (B) and Chumbe (C) in SEM and NEM. Significance level is 0.05

	Bmean ±		Cmean ±		t	p	df	Bmean ±		Cmean ±		t	p	df
Acroporidae	0.2	0.09	2.15	0.39	4.9	<0.0001	38	0.25	0.1	1.7	0.3	4.2	0.0001	38
Pocilloporidae	3	0.6	2.15	0.4	1.1	0.28	38	2.4	0.5	1.3	0.2	1.8	0.07	38
Poritidae	1.9	0.6	2	0.4	0.14	0.9	38	2.6	0.5	1.7	0.4	1.5	0.15	38
”Others”	0.2	0.1	1.45	0.3	3.8	0.0004	38	1.3	0.8	1.4	0.3	0.06	0.9	38

Recent settlement

To detect recent settlement success among coral families, recruits not found in the SEM were extracted from the NEM data. No significant difference in recruitment success among the families was found in Chumbe (one-way ANOVA, F= 0.55, p=0.65) nor in Bawe (one-way ANOVA, F= 1.79, p=0.16, Table 3). There was a difference in density of new recruits by coral families IN Bawe and Chumbe (Table 4, Fig.5). The Acroporidae in Chumbe (mean=0.75±0.2) had a significantly higher recruitment success compared to Bawe (mean= 0.15±0.11, t=2.6, p=0.01, df=38). But Pocilloporidae had higher recruitment success in Bawe (mean=1.6±0.37) than to Chumbe (mean= 0.5±0.15, t=2.6, p=0.02, df=38, Table 4).

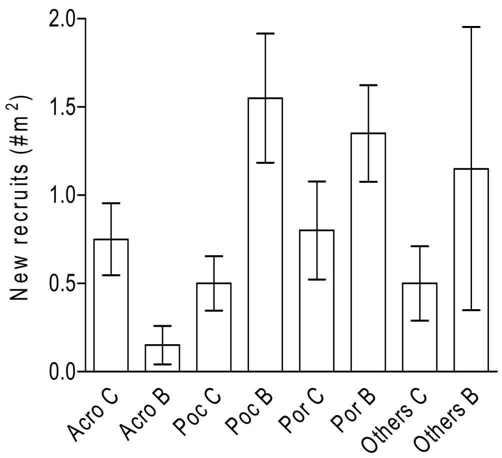

Fig. 5 Numbers of new recruits (= total recruits NEM - recruit SEM), after six months in Chumbe (C) and Bawe (B), Zanzibar for Acroporidae (Acro), Pocilloporidae (Poc), Poritidae (Por) with bars showing standard errors of the mean

Table 3 Summary of ANOVA and Tukey's results comparing density of new recruits in northeast monsoon (NEM), Zanzibar. Lines underneath means join those families which are not significantly different at p=0.05, but break between those who are significantly different

Reef	ANOVA	Tukey's post-hoc test			
Bawe	p=0.15	Poc	Por	Other	Acro
	mean	1.6	1.4	1.2	0.15
Chumbe	p=0.55	Por	Acro	Other	Poc
	mean	0.8	0.75	0.5	0.5

Table 4 Results of t-tests comparing differences between Bawe (B) and Chumbe (C), Zaznibar, in density of new recruits (pr.m²) by coral families

	Bmean ±		Cmean ±		t	p	df
Acroporidae	0.15	0.11	0.75	0.2	2.6	0.01	38
Pocilloporidae	1.6	0.37	0.5	0.15	2.6	0.02	38
Poritidae	1.4	0.27	0.8	0.28	1.4	0.16	38
"Others"	1.2	0.8	0.5	0.21	0.8	0.4	38

Survival

There was no difference in survival rate by recruits among the coral families in Bawe (KW=3.4, P=0.34), or in Chumbe (KW=0.83, p=0.85, Table 5). Also there was no significant difference in survival rate between the coral families when comparing Chumbe and Bawe (Fig. 6, Table 6).

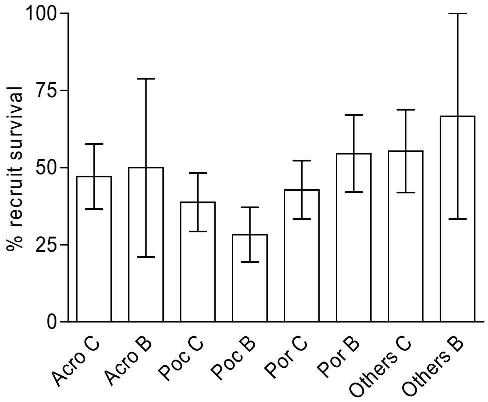

Fig. 6 Six months survival (= marked recruits at time t1- marked recruits at time t2; new recruits not considered) of coral recruits among coral families in Chumbe (C) and Bawe (B), Zanzibar for Acroporidae (Acro), Pocilloporidae (Poc), Poritidae (Por) with bars showing standard error of the means

Table 5 Summary of Kruskal- Wallis test and Dunn-post hoc test comparing survival rates among the coral families. Lines underneath means join those families which are not significantly different at p=0.05, but break between those who are significantly different

Reef	Kruskal-W	Dunns post-hoc test			
Bawe	P=0.34	Others	Por	Acro	Poc
	mean	67	55	50	28
Chumbe	P= 0.85	Others	Acro	Por	Poc
	mean	55	47	43	39

Table 6 Main results from Mann-Whitney U-test showing survival rate differences in the coral families between Bawe (B) and Chumbe (C)

C vs B	Bmean ±		Cmean ±		U	p	df
Acroporidae	50	29	47	11	20	0.96	19
Pocilloporidae	28	8.8	39	9.4	110	0.41	32
Poritidae	55	13	43	9.5	74	0.44	27
Others	67	33	55	13	18	0.75	17

Recruit size and Growth

There was a significant difference in recruit size among the coral families between Bawe and Chumbe. Recruits of Pocilloporidae were significantly larger in recruit size at Chumbe (mean= 880 mm^2±170) compared to Bawe (mean= 410 mm^2±72, t-test, t= 2.82, df=101, p=0.0057). However, the other groups showed no significant difference (Table 7, Fig. 7).

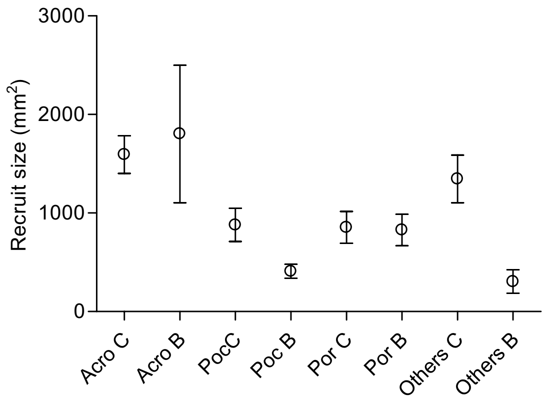

Fig. 7 Coral recruit size during the southeast monsoon (SEM) in Chumbe (C) and Bawe (B), Zanzibar for Acroporidae (Acro), Pocilloporidae (Poc), Poritidae (Por) with bars showing the standard error of the means

There was a significant difference in coral recruit growth rate during six months in the coral families between Chumbe and Bawe (Fig. 8, Table 7). "Others" in Bawe had a low growth rate compared to the "Others" in Chumbe (t=2.8, p=0.01, df=13). However, the other families showed no significant difference (Table 7).

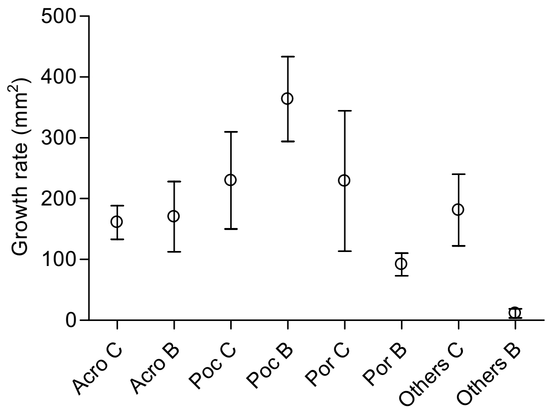

Fig. 8 Growth rates (mm²/6 months) of coral recruits during six months in Chumbe (C) and Bawe (B), Zanzibar for Acroporidae (Acro), Pocilloporidae (Poc), Poritidae (Por) with bars showing the standard error of the means

Table 7 Main results from t-test showing taxonomic differences in recruit size time 1 (t1), and recruit growth rate pr. month, during the six months in Bawe (B) and Chumbe (C), Zanzibar.

	Size							Growth						
	Bmean	±	Cmean	±	t	p	df	Bmean	±	Cmean	±	t	p	df
Acroporidae	1803	698	1593	191	0.3	0.75	46	170	58	161	28	0.14	0.9	1
Pocilloporidae	410	72	880	170	2.8	0.005	101	80	22	230	80	1.8	0.08	16
Poritidae	830	160	854	161	0.1	0.9	75	92	19	229	115	1.2	0.12	11
"Others"	304	119	1347	242	1.6	0.1	31	11	7.6	181	59	2.8	0.01	13

Competition with Corallimorpharia

There was no significant difference in Corallimorpharia cover between the SEM (6.7%±2.4) and the NEM (7.4%±2.4) at Bawe (Mann-Whitney U test, U'=181.5, p= 0.63), nor at Chumbe (SEM 2.1%±0.93, NEM 2.6%±0.99, Mann-Whitney U-test, U'=181.5, p= 0.62). Similarly the Corallimorpharia cover was not different between Chumbe and Bawe during either the SEM (Mann- Whitney U-test, U'=135, p= 0.079) or the NEM (Mann-Whitney U-test, U'= 133, p= 0.071).

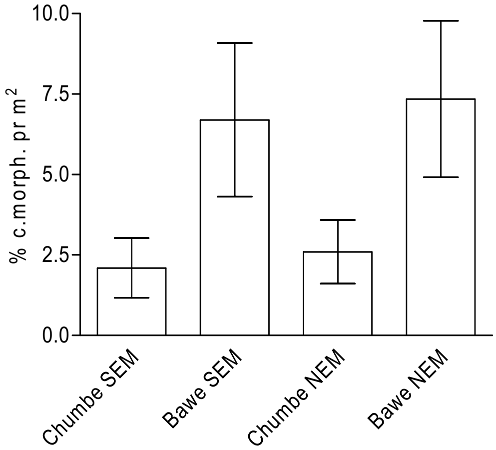

Fig. 9 Difference in Corallimorpharia cover between Bawe and Chumbe, Zanzibar, in the southeast monsoon (SEM) and the northeast monsoon (NEM), with bars showing standard error of the mean

Benthic cover

Bawe and Chumbe were significantly different in benthic composition. There was a significant higher coverage of sand in Chumbe (mean=20%±4.2) compared to Bawe (mean=8%±3.0, U=282, p= 0.02, Fig. 10). However the coverage of live and dead coral did not exhibit a significant difference (Table 8).

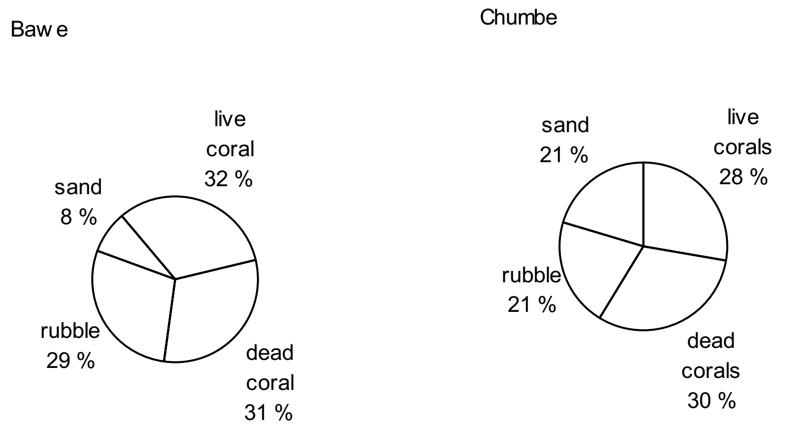

Fig. 10 Substrate composition at the study sites at Bawe and Chumbe, Zanzibar

Table 8 Main results from Mann U-tests testing the benthic composition between Bawe (B) and Chumbe (C), Zanzibar

	U	p	Bmean ±		Cmean ±	
Live coral	200	0.9	32	6.6	28	4.0
Dead coral	201	0.9	31	5.7	31	6.2
Rubble	228	0.4	28	8.5	21	7.0
Sand	282	0.02	8	3.0	20	4.2

Crown-of-thorns starfish

In Chumbe six *A. planci* were observed in the NEM and bleached coral patches caused by starfish predation were occasionally observed. Some of the recruits were affected by this predation. Rangers manually removed *A. planci* in Chumbe. In Bawe nine *A. planci* were observed during the NEM. No fresh bleached patches were observed in Bawe during the field period. The *A. planci* in Bawe were not removed. There was no significant difference in the number of *A. planci* appearing in the two reefs, although the fact that they are removed from Chumbe may give the recruits some protection from this predation.

Discussion

The results of this study suggest that protection of reefs is not necessarily beneficial to coral recruitment. Predation and competition for space may be higher in protected reefs compared to unprotected reefs (Tupper and Juanes 1999; Graham et al. 2003). Chumbe had a higher recruit level during the SEM than Bawe, and a decline in recruit density from the SEM to the NEM. In Bawe no significant difference was observed in recruitment level from one season to the other. This suggests that recruit mortality was higher in Chumbe compared to Bawe, which Fig. 1 in this paper indicates. There is a high level of coral recruits in the SEM in Chumbe following by a drop in recruit density during the NEM, compared to Bawe, which however, shows no significant difference from the SEM to the NEM.

The El Niño southern oscillation in 1998 and subsequent rise in sea temperatures resulted in mortalities of adult coral colonies throughout much of the Indian Ocean. Loss of adult colonies could cause a drop in recruitment levels (Conell et al.1997; Hughes et al 2000). However, the east side of Zanzibar was not severely affected during the 1998 El Niño (West and Salm 2003). Chumbe had a higher coral cover before this event than Bawe and recovered more quickly (Mohammed et al. 2002). The various coral families in Chumbe had equal recruitment density. However, the Acroporidae had a lower density in Bawe. The Acroporidae recruit density in Bawe was also lower than the Acroporidae recruit density found in Chumbe at both seasons (Fig. 3 and Fig.4).

In 1999 Bawe experienced an outbreak of *A. planci*; which negatively affected the coral colonies in Bawe and, combined with the 1998 bleaching, might explain the slow recovery of corals in this area (Mohammed et al.2002). A low density of adult colonies would lead to a poor supply of coral recruits (Conell et al. 1997; Ayre and Hughes 2000; Hughes et al. 2000; Mohammed et al.2002; Harii and Kayanne 2003; Miller and Mundy 2003), which could then lead to a slower recovery of the reef in Bawe.

Marshall and Baird (2000) argue that Acroporidae and Pocilloporidae are among the first corals to settle in open space after a disturbance. This might explain the high abundance of Pocilloporidae in Bawe.

I found no significant difference in recruits' survival between the two reefs. Thus, the results of this study suggest that corals in a disturbed reef had the same survival as on a protected reef (Fig. 6).

Chumbe had significantly larger Pocilloporidae recruits compared to Bawe during the SEM. However, the growth rate during six months showed a significantly higher growth only among the "Others" in Chumbe. That the other coral families did not show a growth difference suggests no advantage to the recruits living in a protected area. Because Pocilloporidae recruits were larger in Chumbe, but showed no growth rate difference to those in Bawe, the Pocilloporidae in Chumbe could have had a higher recruitment level than earlier seasons, suggesting that the recruits in Chumbe are older.

Coral recruit density is highest when grazers are absent. High fish densities lead to a higher predation density on coral spats (Sammarco 1980). Chumbe has been a protected marine area since 1994. It is possible that higher predation pressure on the coral recruits might cause lower recruit survival in Chumbe. The butterfly fish (Chaetodontiadae) preys on corals, especially Pocilloporidae and Acroporidae (Alwany et al. 2003) and they increase in abundance after protection (Russ and Alcala 1998). There is a higher density of butterfly fish in Chumbe than Bawe (Persson and Tryman 2003). This might explain the low level of Pocilloporidae in Chumbe.

Langmead and Chadwick-Furman (1999) claimed that corals could be out-competed by Corallimorpharia. Corallimorpharia cover did not differ significantly between the two reefs in this study. Thus, they do not appear to be a greater threat in either of the reefs.

The benthic composition showed a significant difference between the reefs. The reef in Chumbe had a higher occurrence of sandy patches. The high level of sand could have negatively influenced the coral recruit survival in Chumbe.

In this study I have found that the protected reef had a high density of recruits of the vulnerable coral family Acroporidae, whereas Bawe had a low density of this coral family. However, the survival of recruits in Bawe and Chumbe seemed to be the same, even for Acroporidae. It does not seem that Chumbe has a recruitment success advantage when compared to the unprotected reef in Bawe. During the NEM they have an equal recruitment success. However, Chumbe had a higher density of Acroporidae recruits, and Bawe had a higher density of Pocilloporidae recruits. It is not surprising to find a high level of Pocilloporidae recruits in Bawe, because they are the first to settle in a disturbed area. The low influence of grazers could facilitate a higher density of Pocilloporidae. Surprisingly, there were a lower number of recruits of Acroporidae recruits in Bawe.

This study suggests no favour to coral recruits in protected reef compared to an unprotected reef. The competition and predation from other organisms may increase after protection and negatively affect the coral recruits in the protected reef, as suggested by our mortality results.

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