

Draft 1

**Photo-monitoring of *Acropora palmata* & *Acropora cervicornis* on
Florida reefs: importance of disease & predation to growth &
survivorship**

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ABSTRACT

Caribbean acroporid species have faced extreme declines in abundance since the 1970s, which has led to their identification as candidates for listing under the U.S. Endangered Species Act. Population level recovery will depend on re-colonization by juveniles (fragments or sexual recruits), which are particularly vulnerable to threats such as predation and disease. Photo-monitoring of juvenile *Acropora cervicornis* and *A. palmata* colonies was undertaken in the Florida Keys (USA) to determine the progression and fate of various conditions on the growth and survivorship of recruits. Both healthy colonies and those displaying signs of recent predation were selected haphazardly at several sites, tagged, photographed and measured for size and condition. Colonies were reassessed periodically over the next 18 months. Results suggest that partial mortality decreases growth for both species and among *A. cervicornis*, it leads to increased ?

fragmentation. Disease resulted in complete mortality more often for *A. cervicornis* than *A. palmata*.

Key Words: *Coralliophila abbreviata*, *Hermodice carunculata*, staghorn, elkhorn, disease, fragmentation

INTRODUCTION

Caribbean acroporid corals have experienced extreme and continuing declines estimated at 90 to 98 % throughout their range since the late 1970s. Much of the decline has been attributed to widespread white-band disease (Aronson et al. 2001) but the overall loss is thought to have been exacerbated by frequent and intense bleaching events and physical disturbances as well as other diseases and anthropogenic effects (Porter et al. 2001). In the Florida Keys, decline of acroporid populations occurred in the early 1980s (Jaap et al. 1988) but has continued (Porter & Meier 1992, Miller et al 2002a, b). Since 2000, observations and anecdotal reports were made of new patches of small colonies of both *Acropora palmata* and *A. cervicornis* in the upper Florida Keys that were established, but subsequently disappeared in less than a year (Miller, pers. obs). Thus it was unclear whether or not such observations of new recruitment represented the early stages of population recovery (Rogers et al. 2002). Direct observations on the fate of individual colonies were lacking and so the cause(s) of these losses were uncertain. The current study sought to track some of these small *A. cervicornis* and *A. palmata* colonies to document their fate over time. Here we provide a descriptive summary of general observations and trends in growth and survivorship over 18 months.

METHODS

Study sites in the Florida Keys National Marine Sanctuary (FKNMS) and Biscayne National Park (BNP) were chosen based on the presence of solitary (non-thicket) *Acropora palmata* and *A. cervicornis* colonies (Table 1). At each site, 15 to 20 individual

colonies were chosen to represent the range of colony conditions present at that site (e.g. healthy, preyed upon, etc.) and marked by attaching a numbered aluminum tag to the adjacent substrate. The length, width, and height of each tagged colony were measured and a visual estimate of the portion of the colony covered by live tissue ('% live') was recorded. All colonies were then photographed from several angles with additional photographs taken to document any lesions or abnormalities. A total of 66 *A. palmata* colonies and 68 *A. cervicornis* colonies were tagged (Table 1). Initial surveys were conducted in summer 2002 and the final surveys took place in winter 2003-4. During the approximately 18 month study, colonies were surveyed 4 or 5 times or approximately 3 times per year. Initially, this study targeted juvenile colonies (<40 cm diameter) however larger *A. palmata* individuals (up to 110 cm diameter) were ultimately included since most 'conditions' were only present on larger individuals.

All tagged colonies were assessed for both 'condition' and 'fragmentation' (Table 2) at each survey. Colony condition was categorized as 'healthy', 'remnant', 'diseased', or preyed upon by 'snails' or '*H. carunculata*' as defined in Table 2. Colonies were considered 'fragmented' if they experienced a break that affected the length, width and/or height measurement of the colony and was only scored as present ('fragmented') or absent ('whole'; Table 1). Fragmentation could occasionally be noticed in the field if there was clear evidence of a major break, but comparison of photos between survey intervals provided a more reliable assessment.

Observations from all sites were pooled but analyses were performed on *Acropora palmata* and *A. cervicornis* separately. Colony size was represented by the average of the three dimensions (length, width and height) measured at each survey. Colony growth

rate was estimated from the change in size between surveys, converted to millimeters and divided by the survey interval (d) to adjust for unequal survey intervals. Colonies that fragmented were excluded from all growth comparisons. Multiple regression was used to examine the effects of initial colony size and change in % live on an individual's average growth rate (mm d⁻¹).

Colony condition frequently changed between surveys, thus it was impossible to group colonies by condition for quantitative comparisons. Instead we constructed a matrix based on the colony condition at the start and end of the study. Each colony was assigned to a matrix cell based on its condition at the start and end of the study (e.g. all colonies that began 'healthy' and ended with 'disease' were assigned to a single cell). Three variables were calculated for each cell: a) probability that a colony with a given starting condition would end with a given condition ('colony fate'); b) change in % live and c) colony size. Colony fate was calculated as the total number of colonies in that cell divided by the total number in that row. We term this colony "fate" but it represents only the condition of the colony at the arbitrary end of our study period. Change in '% live' of a colony was calculated for each tagged colony and then averaged for each matrix cell as was the initial size of colonies in a cell.

RESULTS & DISCUSSION

Acropora palmata.

Initially, all tagged *A. palmata* colonies were categorized as healthy, snail-infested, or diseased (Table 3, Fig. 1), ranged in size (average dimension) from 6 to 90 cm (median = 20 cm), and averaged $92 \pm 13\%$ live (mean $\pm$ SD). Most colonies ended the study in the

same condition as they started (Table 1). Forty-three of the 66 colonies began and ended the project healthy. Four colonies (8%) that were initially healthy ended up either remnant ($n=2$) or dead ($n=2$), with mortality not attributable to a specific (directly observed) condition. All five were relatively small colonies and two had been observed with snails during previous surveys. Only 10 out of 65 tagged colonies fragmented over the monitoring period.

Multiple regression analysis showed that both % live and colony size contributed significantly to explaining overall variation in growth rate. Growth rate (mm d^{-1}) increased with increasing colony size ($\beta = 0.63$, $p < 0.00001$), and increasing % live ($\beta = 0.22$, $p < 0.00001$; Fig. 2). This relationship demonstrates that growth rates of small colonies are more influenced by live tissue loss making them more vulnerable to sources of partial mortality which will prolong their time at a vulnerable size. Knowlton et al (1988) also concluded in a similar study that smaller colonies were generally more vulnerable to mortality.

Over the course of the study, a total of 26 *A. palmata* colonies were observed with snails, 7 of these retained snails for the entire period while 10 retained them through 2 consecutive surveys and the remaining 9 were observed with snails at a single survey. The number of snails on a colony ranged from 1 to 11 (median=2). While the number of snails on a given colony changed from survey to survey it is clear that once a colony becomes infested by snails it is likely to remain infested for several months to more than a year. Colonies that retained snails for the duration of the study were larger (Table 3) and had more snails (median = 4) compared to colonies that retained them for two

surveys (median=2) while colonies observed with snails for only one survey had the least (median=1).

Snails were frequently found feeding in an aggregation, producing one large feeding scar on the colony. Larger lesions are less likely to heal (Bak 1983, Lirman 2000) suggesting that the effect of multiple snails feeding on a colony is more than additive. Interestingly, none of the snail infested colonies suffered complete mortality from snail predation. Two small colonies were preyed on by snails and ultimately died, but one was last observed alive with disease rapidly consuming its remaining tissue and the other continued to die slowly after the snails left. The remaining infested colonies (n=17) were abandoned by snails in spite of available host tissue.

Twelve diseased colonies were observed over the course of this survey, 6 of those showed gross signs consistent with white-band disease (WBD) and 6 showed signs consistent with ‘white pox’. In all 6 cases identified as WBD, tissue loss began at the base of the colony and proceeded up the underside of the branch and stopped leaving most of the topside covered with live tissue. Two of the six colonies displayed active WBD through at least 2 surveys. Only one colony started and ended this study with active WBD (Table 3); however at one survey it was inactive (i.e. no recent mortality or ‘white band’ observed) and then became active again at the next survey but on a different part of the colony than at the start.

Once the disease front stalled and there were no traces of active WBD, the remnant tissue had a distinctive pattern (Fig. 1c) where only the top surfaces remain alive. This distinctive pattern has been observed at many other sites in the upper Florida Keys (author’s unpubl data) and although active WBD has not been observed on these

colonies, the remnant tissue pattern suggests that these colonies may have survived a WBD 'infection'. Once the WBD stopped, the remnant live tissue had a normal, healthy appearing margin/border but was not observed to 're-sheet' the dead skeleton over the duration of this survey so it is unknown how long this pattern persists or if WBD will become active again on these colonies.

Lesions consistent with white pox¹ (see Rodriguez-Martinez et al. 2001 for illustration) were observed on a total of 6 tagged *A. palmata* colonies at all sites except Marker 3 Reef. Affected colonies had large, irregular, scattered, multi-focal lesions (Fig. 3a) and could be seen on all branch surfaces (upper, lower and sides). Pox lesions frequently began healing between surveys but were never completely healed by the following survey.

Similar lesions were found to be associated with fish fecal material. Certain individual colonies were repeatedly observed with small piles of fish feces on the upper surfaces of the colony (Fig. 3b). Occasionally if the fecal material was present and fanned off, a lesion was observed (Fig. 3 c-d). Both the lesions and the piles of fecal material were frequently crescent shaped (Fig. 3 b-d), and were commonly seen at Marker 3 Reef and occasionally at other sites. This type of lesion was not categorized as white pox because they were smaller, completely gone and in some cases new ones appeared by the following survey.

Acropora cervicornis. At the initial survey in summer 2002 all 68 tagged individuals were categorized as healthy (Table 4, Fig. 4), snail-infested, or having signs of predation

by *Hermodice carunculata*. Tagged colonies ranged in size from 3 to 35 cm (median=17cm) and $96 \pm 6\%$ live (mean $\pm$ SD) at the start of the survey period.

Multiple regression analysis found that initial colony size contributed significantly to explaining overall variation in individual average growth rate (Fig. 5) but change in % live did not. Growth rate (mm d^{-1}) increased as initial colony size increased ($\beta=0.42$, $p<0.0006$), but was not significantly affected by change in % live ($\beta=0.16$, $p=0.1768$; Fig. 5)

Predation by *Hermodice carunculata* was very common at all sites. In fact, at least one feeding scar was found on nearly all tagged colonies at some point in the survey so we chose to separate those with few scars from those that had more than 1/3 of their branch tips denuded and thus were apparently 'more affected'. Branch tips denuded by *H. carunculata* were gradually colonized by algae and always appeared long dead by the next survey. The dead tips occasionally appeared eroded/chiseled and frequently were completely broken off leaving blunt nubs (Fig. 4b) that were ultimately re-sheeted with live tissue. Parrotfish grazing on these dead tips has been hypothesized (Antonius 1975) to erode or remove them. While not directly observed, our observations are consistent with this scenario.

Nearly half (46%) of the 68 tagged colonies fragmented during the monitoring period. Several colonies that fragmented, particularly those in which the break occurred near the distal end of the branch, were observed to resheet the fracture with healthy live tissue but were not observed to form an axial polyp and continue growth resulting in a bulbous end or 'stump' like those associated with *Hermodice carunculata* predation. Prior to

¹ 'white pox' has been associated with the bacteria *Serratia marcescens* (Patterson et al 2002) however the lesions observed in this study were not examined for the presence of this pathogen thus use of the term white pox refers only to gross disease signs and not etiology.

complete re-recovery by live tissue, a new protobranch would occasionally form growing in a different direction than the original branch.

During the course of this study, a disease outbreak occurred on *A. cervicornis* at White Bank Dry Rocks (Williams & Miller, subm) affecting more than 80% of the tagged colonies and the surrounding population. Fifteen colonies were observed with recent rapid tissue loss (Fig 4c-d) not consistent with WBD in *Acropora cervicornis* (Williams & Miller, subm.). However, only 4 of these 15 ended the survey with active disease, the remainder were dead (n=5) or remnant (n=6). Four out of 18 colonies that were initially healthy at Elkhorn reef lost substantial tissue to an unknown (not observed) condition (Table 2) and ended up as remnant or dead colonies (table 2). Though tagged *A. cervicornis* at Elkhorn reef were not observed with active disease, it was observed on untagged colonies in the general vicinity so it is plausible that the four colonies with unknown fate at that site were affected or killed by disease. In contrast, none of the tagged colonies at Anniversary Reef ended up dead or remnant and none were observed with active disease even though some colonies on the edge of this patch were observed with disease. Consequently the probability of becoming diseased presented in Table 4 do not directly show the influence of disease, however, they do reflect the probability of a colony suffering substantial partial (remnant) or total mortality (dead). In order to capture rapidly progressing conditions such as disease in *A. cervicornis*, survey intervals should be slightly shorter than 4 or 5 months. Surveys every 6 to 8 weeks would likely have allowed for direct observation of disease at the sites surveyed.

Ten tagged colonies were observed with snails at some point during this survey but only one colony maintained them throughout the study. Three retained snails for at least

2 consecutive survey periods and 6 had them at only one survey. Snail infested colonies had between 1 and 5 snails (median= 2 snails). In contrast to *A. palmata*, it was difficult to find snail infested *A. cervicornis*, in fact they were completely absent from Anniversary reef.

CONCLUSIONS

- Colonies, particularly larger ones, may be affected by more than one 'condition' (simultaneously or sequentially) making it difficult to partition effects of individual conditions.
- Partial mortality affects growth rate in *Acropora* spp. The condition associated with tissue loss did not influence the growth rate.
- Partial mortality affects fragmentation in *A. cervicornis*; sample size was too small to determine this for *A. palmata*, but it is possible that size has more influence than tissue loss on fragmentation.
- *Coralliophila abbreviata* may remain on a single host colony for extended periods of time.
- Both predators and disease frequently leave remnant living portions of a colony.

Not sure that they really can say this especially if mortality were at Bonaire tip

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REFERENCES

- Antonius A (1975) New observations on coral destruction in reefs. In Multer HG (ed) Field guide to some carbonate rock environments: Florida Keys and western Bahamas. Contribution no. 40, dept. Earth Sci., Fairleigh Dickinson University, Madison, NJ.
- Aronson RB, Precht WF (2001) White-band disease and the changing face of Caribbean coral reefs. *Hydrobiol* 460: 25-38.
- Bak, RPM, 1983. Neoplasia, regeneration and growth in the reef-building coral *Acropora palmata*. *Mar. Biol.* 77:221–227.
- Jaap WC, Halas JC, Muller RG (1988) Community dynamics of stony corals (Milleporina and Scleractinia) at Key Largo National Marine Sanctuary, Florida, during 1981–1986. *Proc 6th Int Coral Reef Symp* 2:237–243
- Knowlton N, Lang JC, Keller BD (1988) Fates of staghorn isolates on hurricane-damaged reefs in Jamaica: the role of predators. *Proc 6th Int Coral Reef Symp.* 2:83-88

Lirman D (2000) Lesion regeneration in the branching coral *Acropora palmata*: effects of colonization, colony size, lesion size, and lesion shape. Mar. Ecol. Prog. Ser. 197: 209–215.

Miller MW, Bourque AS, Bohnsack JA (2002a) An analysis of the loss of acroporid corals at Looe Key, Florida, USA: 1983–2000. Coral Reefs 21:179–182

Miller MW, Baums IB, Williams DE, Szmant A (2002b) Status of Candidate coral, *Acropora palmata*, and its snail predator in the upper Florida Keys National Marine Sanctuary: 1998-2001. NOAA Tech Memo NMFS-SEFSC-479, 26p

Patterson KL, Porter JW, Ritchie KB, Polson SW, Mueller E, Peters EC, Santavy DL, Smith GW (2002) The etiology of White Pox, a lethal disease of the Caribbean Elkhorn coral, *Acropora palmata*. Proc Natl Acad Sci 99(13):8725-8730

Porter JW, Meier OW (1992) Quantification of loss and change in Floridian reef coral populations. Am Zool 32:625–640

Porter JW, Dustan P, Jaap WC, Patterson KL, Kosmynin V, Meier OW, Patterson ME, Parsons M (2001) Patterns of spread of coral disease in the Florida Keys. Hydrobiol 460:1-24

Precht WF, Bruckner AW, Aronson RB, Bruckner RJ (2002) Endangered acroporid corals of the Caribbean .Coral Reefs (21)41-42

Rodríguez-Martínez RE, Banaszak AT, Jordán-Dahlgren E (2001) Necrotic patches affect *Acropora palmata* (Scleractinia:Acroporidae) in the Mexican Caribbean. Dis Aquat Org 47:229-234.

Williams DE, Miller MW (Subm) Coral disease outbreak: pattern, prevalence, and transmission. (in review) Mar Ecol Prog Ser (11/2003).

Table 1: Sites and samples sizes for monitoring study of *Acropora* spp. juvenile colonies

Site	Coordinates	# <i>A. palmata</i>	# <i>A. cervicornis</i>
Anniversary (BNP)	25° 23.293 N, 80° 09.869 W	--	26
Elkhorn (BNP)	25° 21.714 N, 80° 09.937 W	19	20
Marker 3 (BNP)	25° 22.395 N, 80° 09.614 W	18	2
North Dry Rocks (FKNMS)	25° 07.835 N, 80° 17.613 W	11	--
Sand Island (FKNMS)	25° 01.107 N, 80° 22.044 W	18	--
White Bank Dry Rocks (FKNMS)	25° 02.595 N, 80° 22.156 W	--	19
total		66	68

Table 2. Classifications for condition and fragmentation colony assessment assigned to each colony at each survey.

Colony assessment	Classification	Definition
I. Condition	Healthy	At least 50% live with no signs of recent* mortality and maintained or increased tissue cover over the course of the study.
	Snails	<i>Coralliophila abbreviata</i> (corallivorous snails) present on colony.
	Diseased	Recent* mortality consistent with white band disease, white pox or other unidentified recent mortality (Precht et al. 2002, Rodriguez-Martinez et al. 2001).
	Remnant	No signs of recent tissue loss but less tissue than at initial survey.
	<i>H. carunculata</i>	At least 1/3 of branch tips denuded of live tissue indicative of fireworm predation.
II. Fragmentation	Whole	No breakage detected based on photo comparison or field observation.
	Fragmented	Branch break that affects the length, width and/or height of a colony.

* Recent mortality was defined as any areas of bare, white exposed skeleton with little or no algal colonization and intact calyx structure. Areas of the colony with dense algal colonization or eroded calyx structure were identified as 'long dead'.

Table 3. Matrix showing a) probability of colony fate (see text for explanation) b) change in % live tissue coverage of a colony and c) the initial colony size (cm) grouped by condition at the start and end of the study for tagged *Acropora palmata* from all sites. The condition at the start of the study is read across rows of the matrix and the condition at the end is read down the columns. For example, colonies that began the study infested with snails (*Coralliophila abbreviata*) had a 44% chance of ending the study infested with snails, and the seven colonies of this fate lost $24 \pm 7.5\%$ (mean $\pm$ SE) of their live tissue coverage and began the study as a 56 ± 8.1 cm (mean $\pm$ SE) colony.

		Probability of colony fate				
		Healthy	Snails	Disease	Remnant	Dead
Start	n	43	10	1	8	4
	Healthy	85%	6%		4%	4%
	n 47	40	3		2	2
	Snails	19%	44%	6%	19%	13%
	n 16	3	7	1	3	2
	Disease				100%	
	n 3				3	

		Change in % live tissue coverage				
		Healthy	Snails	Disease	Remnant	Dead
Start	Healthy	-4%	-68%		-28%	-100%
	SE	2.8%	31.3%		12.5%	0.0%
	Snails	-33%	-24%	-70%	23%	-73%
	SE	13.3%	7.5%	*	13.2%	12.5%
	Disease				-44%	
	SE				11.6%	

		Initial colony size (cm)				
		Healthy	Snails	Disease	Remnant	Dead
Start	Healthy	27	16		26	7
	SE	3.5	6.3		18.2	1.3
	Snails	17	56	20	17	19
	SE	7.8	8.1	*	10.1	2.0
	Disease				27	
	SE				12.8	

* indicates no SE due to sample size <2

Table 4. Matrix showing a) probability of colony fate (see text for explanation) b) change in % live tissue coverage of a colony and c) the initial colony size (cm) grouped by condition at the start and end of the study for tagged *Acropora cervicornis* from all sites. The condition at the start of the study is read across rows of the matrix and the condition at the end is read down the columns. For example, colonies that began the study with signs of predation by *Hermodice carunculata* had a 50% chance of ending the study healthy, and the six colonies that began and ended this way increased their live tissue coverage by $6 \pm 2\%$ (mean $\pm$ SE) and began the study as a $17 \pm 3\text{cm}$ (mean $\pm$ SE) colony.

		Probability of colony fate					
		Healthy	Hermodice	Snails	Disease	Remnant	Dead
Start	n	31	9	2	4	15	7
	Healthy	48%	13%		6%	19%	13%
	n 52	25	7		3	10	7
	Hermodice	50%	17%		8%	25%	
	n 12	6	2		1	3	
	Snails			50%		50%	
	n 4			2		2	

		Change in % live tissue coverage					
		Healthy	Hermodice	Snails	Disease	Remnant	Dead
Start	Healthy	0%	-24%		-67%	-74%	-75%
	SE	0.5%	5.3%		14.9%	9.4%	16.6%
	Hermodice	6%	8%		-80%	-88%	
	SE	1.6%	2.5%		*	8.0%	
	Snails			-13%		-88%	
	SE			32.5%		8.0%	

		Initial colony size (cm)					
		Healthy	Hermodice	Snails	Disease	Remnant	Dead
Start	Healthy	17	11		33	19	13
	SE	1.3	2.1		0.9	2.2	2.0
	Hermodice	17	21		25	27	
	SE	2.8	10.3		*	6.5	
	Snails			27		27	
	SE			0.2		6.5	

* indicates no SE due to sample size <2

FIGURE CAPTIONS

Figure 1. Time series showing the growth and progression of a) healthy, b) snail infested and c) White band diseased tagged colonies. a) Healthy colony from Elkhorn Reef growing on average 3.2 mm d^{-1} and maintaining 100% live tissue coverage; b) Snail-infested colony from Elkhorn Reef with one snail feeding on the underside of the colony for the first two surveys. By the third survey, there are 3 snails and the underside of the colony has recent tissue loss consistent with disease (not visible in photo). This colony grew on average 1.8 mm d^{-1} and lost 75% of its live tissue. c) White band diseased colony from Marker 3 reef; although there is no active disease at the first survey (day 0), it has started on the underside of the branch by the 2nd survey and at the 3rd it has begun to wrap around to the topside of the branch (see side view at inset). At the 4th survey that branch was completely dead and the band on another branch began to wrap to the topside. This colony grew on average 0.8 mm d^{-1} and lost 40% of its live tissue.

Figure 2. Scatterplot of the initial size, change in % live, and average growth rate (see text for details) for each tagged *Acropora palmata* colony.

Figure 3. White pox and similar lesions on *Acropora palmata*. a) Typical ‘white pox’ type lesions (scale in photo is 30 cm). Note lesions are large ($>10 \text{ cm}$), irregular in shape and scattered on horizontal and vertical surfaces of the colony. b) Lesions associated with fish fecal material; relatively small in size and variable in shape but frequently round or crescent shaped and typically found on upper surfaces of colony. c)

Fish fecal material encountered on an *A. palmata* branch. d) Same branch with fecal material fanned off, note the crescent shaped lesion underneath.

Figure 4. Time series showing the growth and progression of a) healthy, b) *Hermodice carunculata* predation and c) White band diseased tagged colonies. a) Healthy colony from Elkhorn Reef growing on average 4.8 mm d^{-1} and maintaining 100% live tissue coverage; b) Colony from Elkhorn Reef, that was initially healthy and then was preyed on by *Hermodice carunculata*. This colony grew on average 4.3 mm d^{-1} until nearly all branch tips were eaten after which it averaged only 0.9 mm d^{-1} and lost an estimated 10% of live tissue.. c) Close up of disease observed at White Bank Dry Rock characterized by rapid tissue loss. d) Colony with rapid tissue loss over short time intervals to show the rapid progression. New lesions appear scattered over colony at each survey. Note that at the final survey the colony is nearly dead but has some remnant portions of live tissue and it has fragmented since the previous survey.

Figure 5. Scatterplot of the initial size, change in % live, and average growth rate (see text for details) for each tagged *Acropora cervicornis* colony

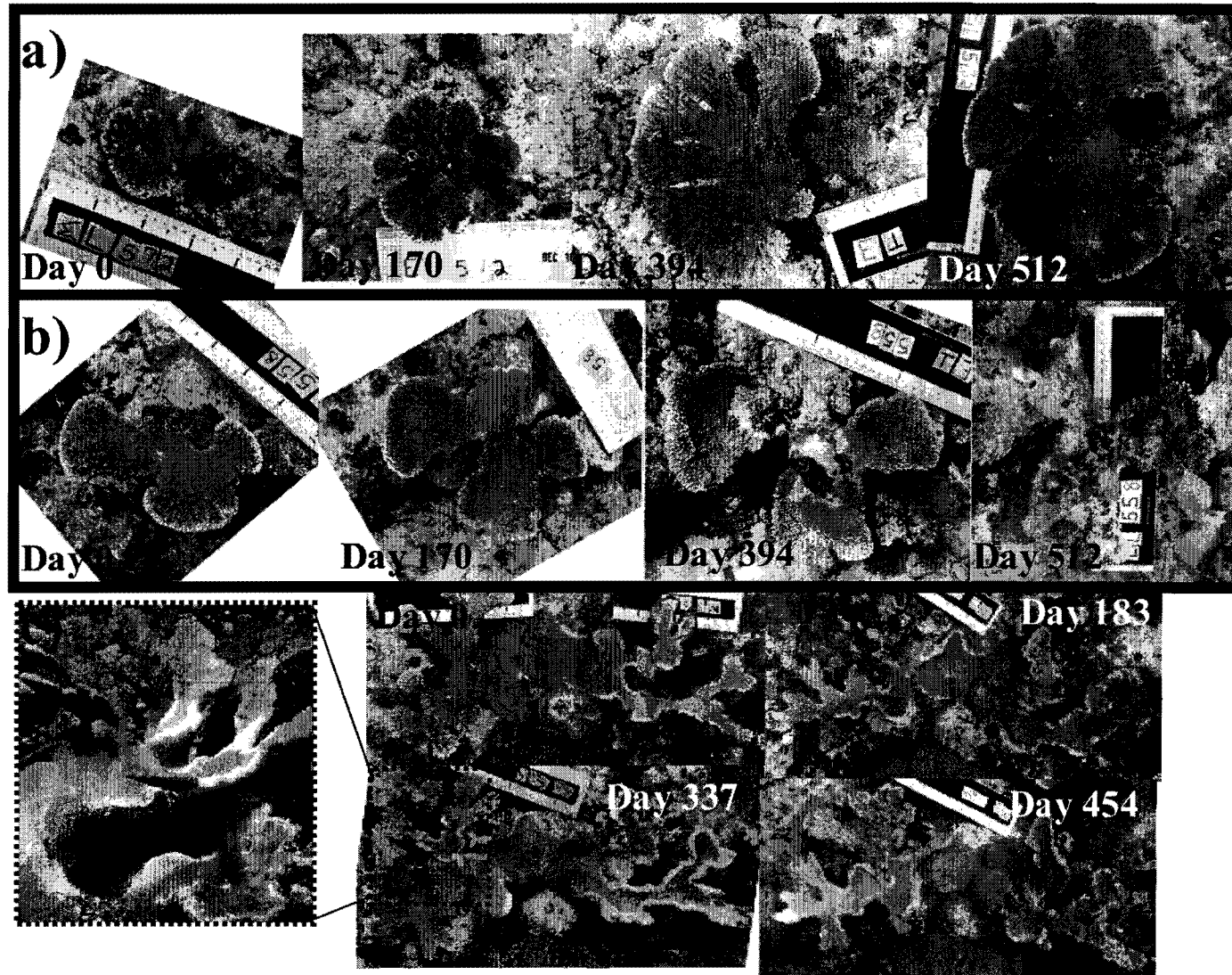


Figure 1

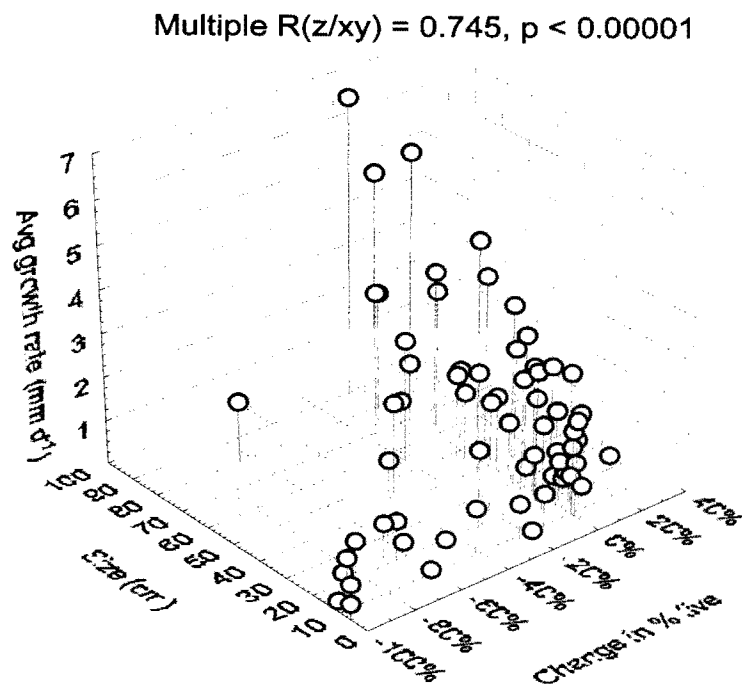


Figure 2

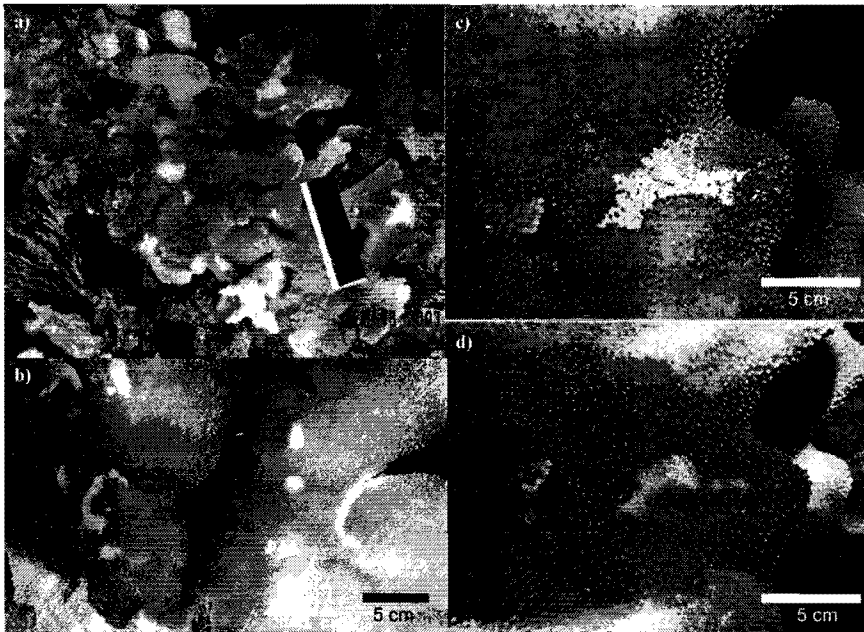


Figure 3

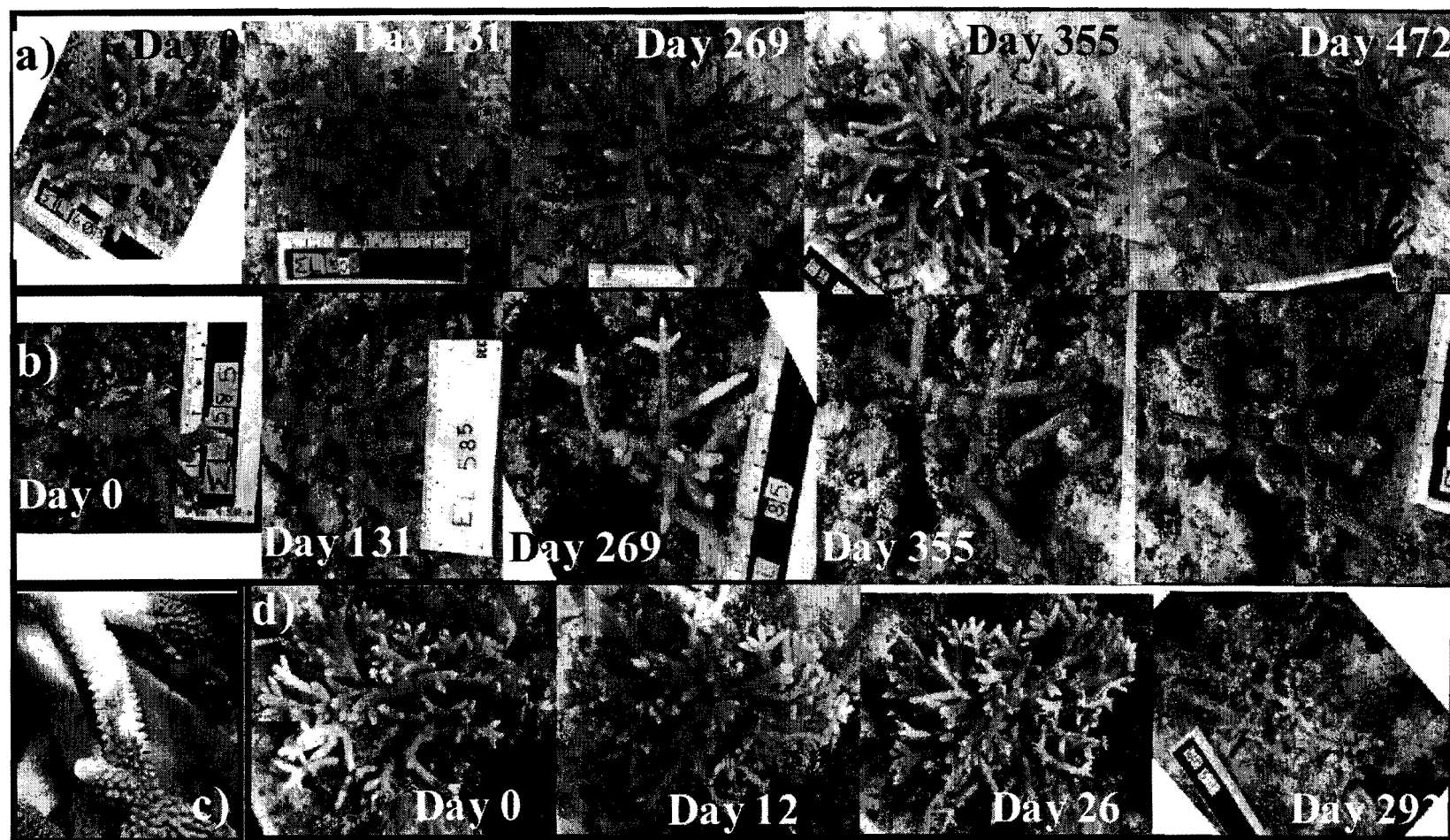


Figure 4.

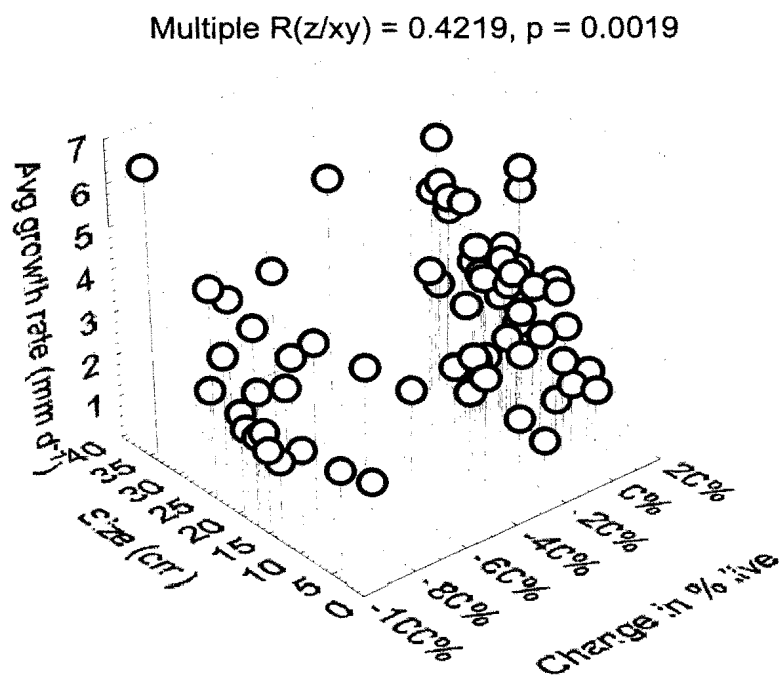


Figure 5.