Interim report on effectiveness of corallivorous snail removal

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Background

There has been a marked decline in the abundance of the Caribbean elkhorn coral, *Acropora palmata* in recent decades. Natural and anthropogenic factors such as disease, storm damage, and bleaching interact synergistically to affect the health and abundance of these corals. However, the effects of predation by invertebrates on corals in the Florida Keys and Caribbean are often overlooked as a major source of disturbance on corals. The corallivorous snail, *Coralliophila abbreviata*, can be found grazing on at least 14 species of scleractinian corals in the Caribbean (Miller, 1981) including coral genera *Acropora, Montastraea, Diploria,* and *Agaricia. Acropora palmata* appears to be a preferred host for *C. abbreviata,* supporting faster growth and higher fecundity compared to other coral hosts (Johnston and Miller, 2007). *Coralliophila abbreviata* can consume *A. palmata* tissue at a rate of up to 16 cm^2 $snail^{-1}$ day^{-1} (Brawley and Adey, 1982) and may account for ~ 25% of chronic tissue loss on *A. palmata* colonies in the Florida Keys (Williams and Miller, in press). These predators may indirectly contribute to further live tissue loss by vectoring disease conditions among host colonies (Williams and Miller, 2005, Sutherland et al., 2010) or even attracting other predators such as butterflyfish (Brawley and Adey, 1982).

Because the snails are fairly sedentary predators, remaining on a single host colony for weeks or longer (as long as live tissue remains available) we proposed that snail removal could prove to be a useful management strategy for decreasing the amount of predation on corals as well as possibly reducing the spread of diseases. We initiated a pilot experiment to characterize the costs and benefits of manually removing snails at a moderate spatial scale (150m^2 plots), replicated at six sites in the upper Florida Keys. This interim report describes the effort expended and effectiveness in terms of maintaining reduced snail densities and decreasing predation. The effectiveness in terms of overall *A. palmata* colony fate is being evaluated within our long-term *A. palmata* monitoring effort and will be reported in the future.

Methods

Pre-existing, long-term *Acropora palmata* study plots at six sites in the upper Florida Keys National Marine Sanctuary (FKNMS) were chosen for this experiment. Each of the sites included three plots each of which was assigned to a snail treatment: 1) removal of snails from *Acropora palmata* colonies only ("Ap Only"), 2) removal of snails from all host corals in the plot ("All Hosts"; mainly *A. palmata, Diploria* spp., *Montastraea* spp. and *Agaricia* spp.), and 3) "Control" in which snails were counted on the host corals in the plots, but the snails were not removed.

Removal of *Coralliophila abbreviata* from the host corals was done by 2 SCUBA divers that were experienced in finding this somewhat cryptic species. Individual host corals were searched, and when snails were found in the removal plots, the diver recorded the host species and the number of snails on the colony and the snails were removed and pooled in baggies according to host species. Due to the high abundance and small size of *Agaricia* spp., it was not possible to rigorously record snails per colony. However, when *Agaricia* colonies were encountered in the All Hosts and Control plots, they were searched and snails found in the All Host plots were removed. Snail shell length was measured to the nearest mm using vernier calipers. All removed snails were killed and returned to the reef (i.e. trophic and shell resources retained within the site). Initial removal was conducted during 14-16 June, 2011. Two subsequent surveys (21 d and 75 d following the initial survey) were conducted in the Ap Only and All Hosts plots to remove and measure any snails that either were overlooked in the previous removal efforts or had since migrated back into the plots. We ran a factorial ANOVA on the percent colonies with snails from survey one in order to test for differences between hosts and treatment.

Results

Effectiveness of Removal

We removed a total of 330 snails from *A. palmata,* 63 from *Diploria* spp., 163 from *Montastraea* spp., and 55 from other corals for a total of 661 snails removed during survey one from all treatments (Table 1). We also removed 40 snails from *A. palmata,* 1 from *Montastraea* spp., and 6 from other colonies in survey two for a total of 47 snails. Lastly, we removed 39 snails from *A. palmata,* 9 from *Montastraea* spp., and 1 from other colonies during survey three for a total of 49 snails removed and a grand total of 707 snails removed over the three surveys from all colonies in all plots.

The percent of colonies with snails present ('snail occupancy' from here forward) at the initial survey did not vary significantly among hosts or the treatments ($F_{2,35} = 0.741$, $p = 0.484$; Fig. 1); hence these constituted appropriately comparable experimental treatments. Colonies in the control plots had the most snails while the *Acropora* only plots had fewer snails (Fig. 1).

The number of snails found on *Acropora palmata* for the "All Hosts" removal treatment plot and the "Ap Only" removal treatment plot decreased in the latter surveys compared to the initial survey (Fig. 2). Although we cannot determine whether the snails in surveys 2 and 3 were overlooked in the initial removal survey or if additional snails migrated into the plots, there were significantly fewer snails following the initial survey, suggesting that removal of snails by divers on a short time scale of 3 months can reduce the number of snails present on colonies by over 80%. In addition, the average snail size on *A. palmata* colonies was smaller in the latter surveys compared to the initial survey for both the "All Hosts" removal and the "Ap Only" removal treatments (Fig. 3).

Based on routine surveys of tagged *A. palmata,* there were substantially fewer feeding scars in the treatment (removal) plots following the removal than were observed in the surveys preceding the removal (Before vs. After). Although the prevalence of feeding scars can vary the decrease was also greater than that observed in the control plots where snails were not removed (Control vs. Impact; Fig. 4).

Effort

The time required to search and remove snails from a 150m^2 plot varied based on the size and abundance of host colonies and numbers of divers. Most plots were searched with a two person dive team, but three divers were used in four of the 12 study plots. The initial removal was conducted over a 4 day period (6/13-6/16/11) with the average dive time totaling 73 minutes per diver, which equates to 2,044 underwater minutes (34 person hours) to search & remove snails from a total of 1800m^2 with more than 640 coral colonies. This breaks down to 1:08 min for a diver to search a square meter or less than 3 minutes per coral. The initial survey included ancillary recording tasks that would likely not be necessary outside of an experimental setting. During the 2nd and 3rd surveys the same number of colonies was surveyed and snails were collected but divers only had to record data when snails were found so on average it took 30 seconds per square meter or 1 minute per coral colony per diver, hence confirming that 'maintenance' removal surveys require about half of the effort of initial removal surveys.

Synthesis

On the short term, removal of snails by divers has had noticeable impacts on *Acropora palmata* colonies in this study. Although snails were still found during surveys 2 and 3, indicating that the initial removal did not completely eradicate all snails present in the study plots, removal during survey 1 did dramatically reduce snail abundance and size. In addition to potentially reducing the amount of tissue they will consume, the shift to smaller individuals preying on coral hosts may also alter the population-sex ratio such that there are likely fewer females available for mating (Fig. 3). If some of the remaining males transition to females (they are protrandrous hermaphrodites), they will be smaller than the females found prior to the removal, resulting in fewer offspring (Johnston and Miller, 2007). Additionally, the findings thus far do not indicate lower snail recurrence on *A. palmata* when snails were removed from all hosts (Fig. 2), suggesting that removal of snails from only the *A. palmata* host colonies may be equally effective at reducing predation impact while requiring less effort. The effectiveness of this method and any benefits to the *A. palmata* population on the long term will continue to be evaluated over at least a two year period.

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Host spp.	Treatment	# Colonies	# snails		
			S1	S2	S3
A. palmata	Ap Only	191	121	18	10
	All Hosts	207	147	22	29
	Control	101	62	--	--
Montastraea	Ap Only	--	--	--	--
	All Hosts	29	135	1	9
	Control	29	28	--	--
Diploria	Ap Only	--	--	--	--
	All Hosts	9	20	0	0
	Control	12	43	--	--

Table 1 The number of snails counted (Controls) and/or collected (three treatments) on every colony for surveys 1, 2, and 3 in the three treatments (All Hosts, Ap Only, and Control) and for each host (*A. palmata, Montastraea, Diploria)* with the number of colonies surveyed for each treatment. Control plots were not included in Surveys 2 and 3.

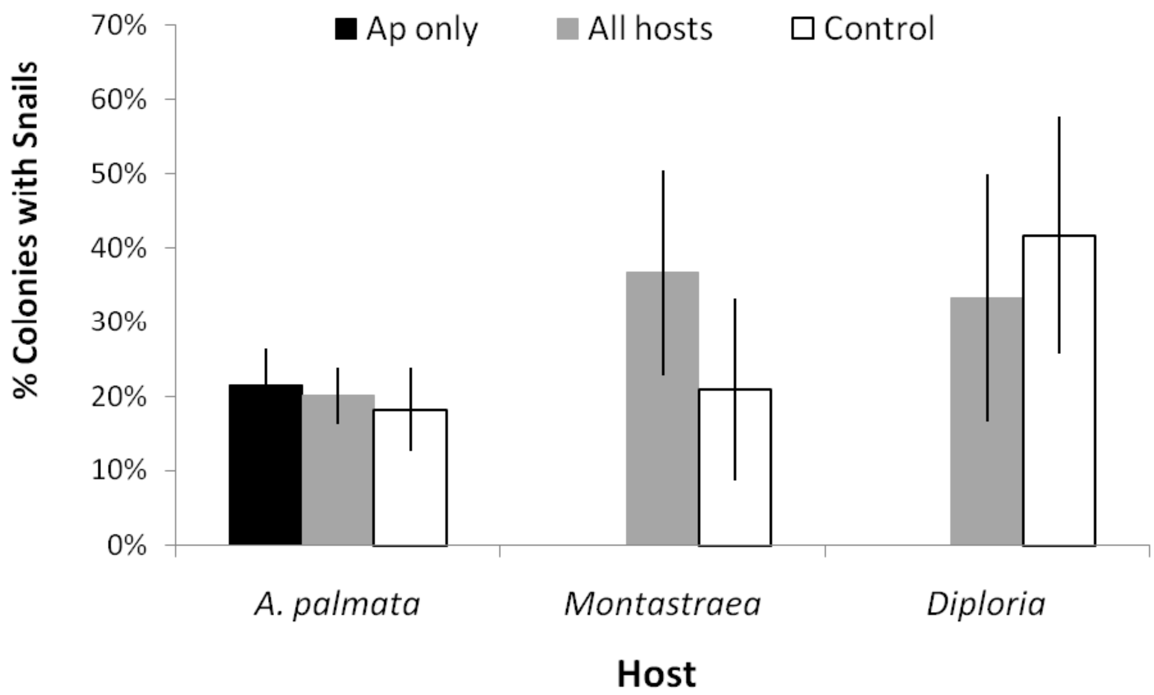

Figure 1 Percent of host colonies with snails for each snail treatment at the initial survey pooled across sites. "Ap Only" refers to the treatment where snails were removed from only *Acropora palmata* colonies and left in place on the other hosts, whereas "All Hosts" refers to the removal of snails from all coral hosts in the plot, and no snails were removed in the control treatment. Error bars represent the standard error and n = 6 for all treatments.

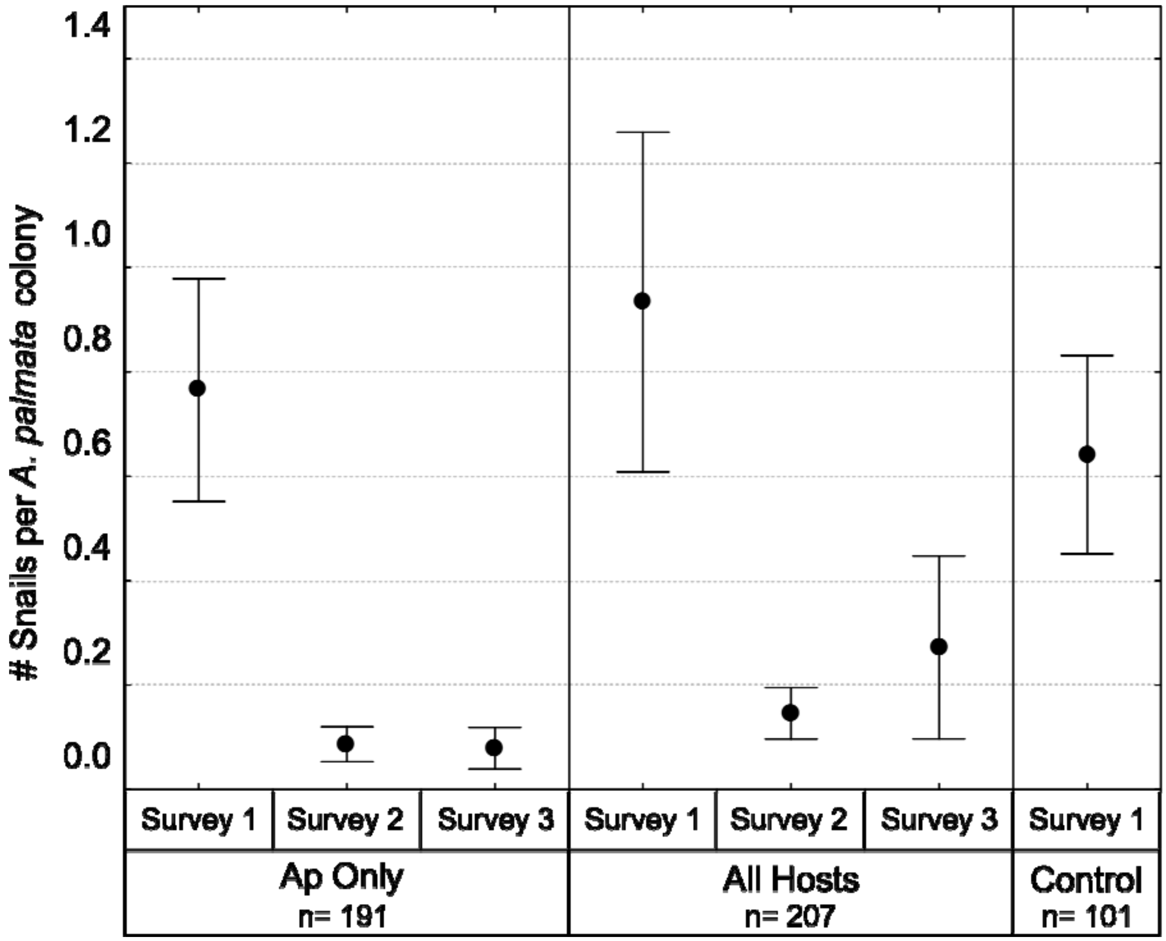

Figure 2 **The mean (± SE) number of snails found on *Acropora palmata* colonies in the removal treatments for three surveys and the control treatment plot for survey one. The initial survey (Survey 1) was done between 14-16 June, 2011, Survey 2 completed 21 d later (~ 7 July, 2011), and Survey 3 was completed 75 d after the initial survey (~ 20 September, 2011).**

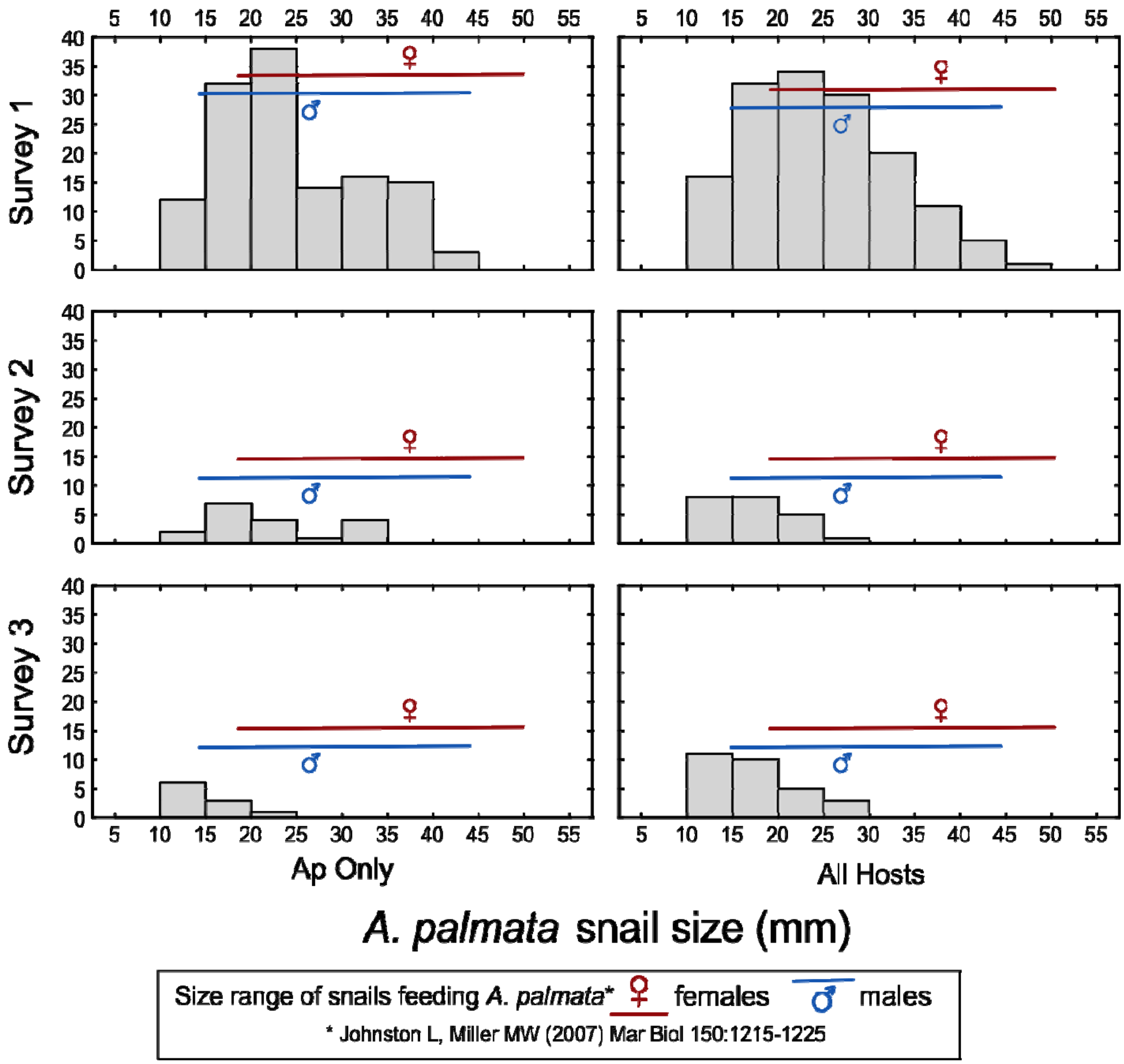

Figure 3 **The size frequency distribution of the snails found *Acropora palmata* colonies only in the removal treatments for the three surveys. The initial survey (Survey 1) was done 14-16 June, 2011, Survey 2 completed 21 d later (~ 7 July, 2011), and Survey 3 was completed 75 d after the initial survey (~ 20 September, 2011). The blue ♂ symbol represents the average shell length (27 ± 16 mm) for male snails on *Acropora* while the ♀symbol represents the average shell length (38 ± 15 mm) for female snails on *Acropora* colonies and the bars represent the range based on the Johnston and Miller (2007) study of *Coralliophila abbreviata* in the upper Florida Keys.**

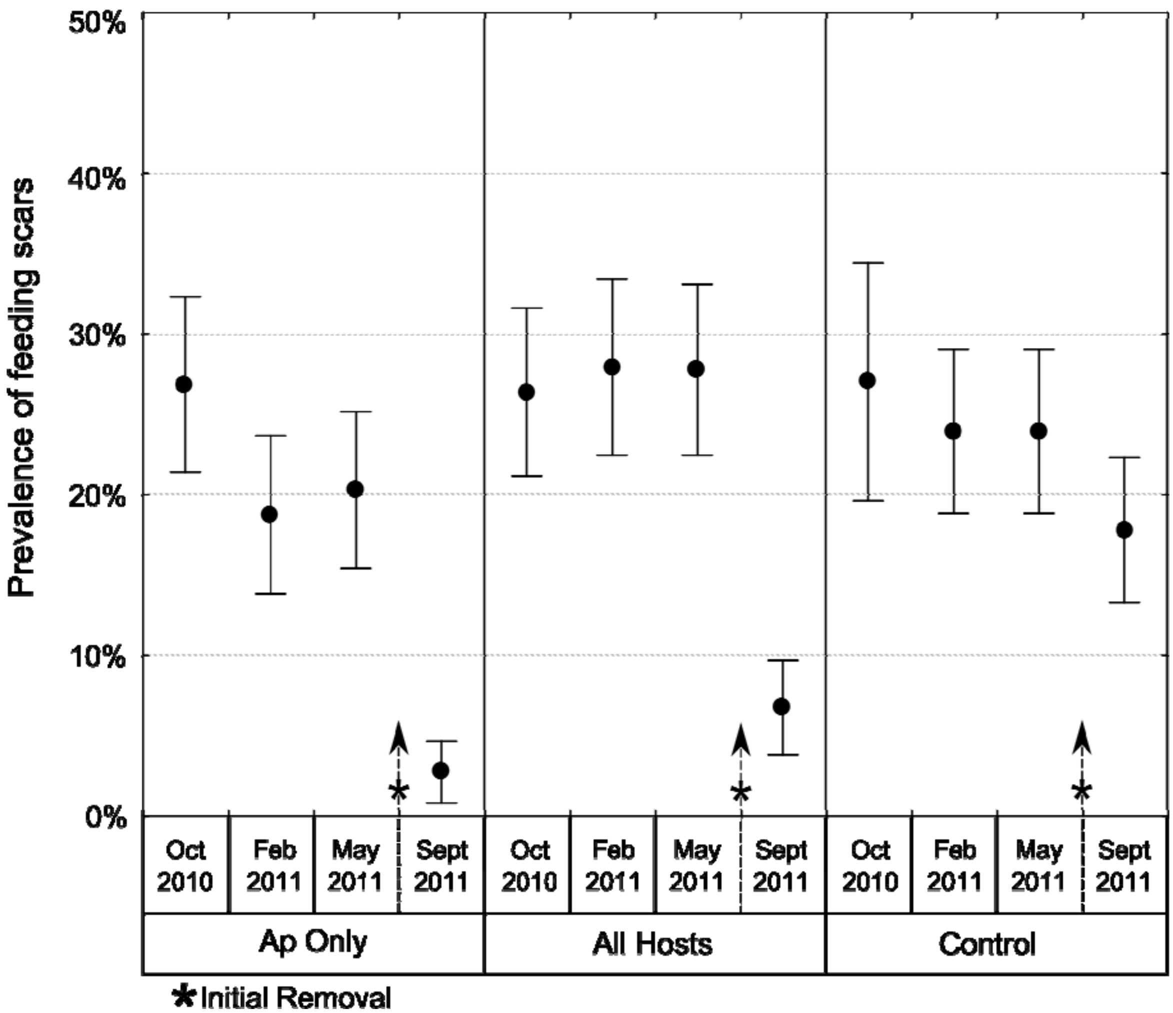

Figure 4 The prevalence of feeding scars on tagged Acropora palmata colonies in the study plots for three observations prior to the initial removal effort (Survey 1; June 2011) and at Survey 3 (Sept 2011). The study plots are pooled by treatment (Ap Only, All Hosts, and the Control). The means ± SE are represented with an n = 6.

References

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