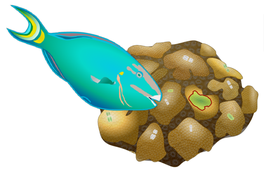
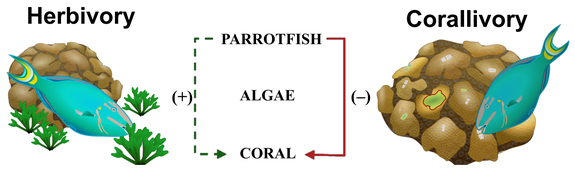


Recovery of endangered *Orbicella annularis* corals from parrotfish predation

Hannah Rempel[1], Kelly Bodwin[2], Clinton Francis[1], Benjamin Ruttenberg[1]
Biological Sciences Department[1], Statistics Department[2], California Polytechnic State University

INTRODUCTION

Herbivorous parrotfishes (*Scarinae*) play an important role in reducing coral-algae competition by grazing reef algae. Yet, some species also feed on live coral (a behavior known as corallivory), which can reduce coral growth, fecundity and survivorship[1-3].



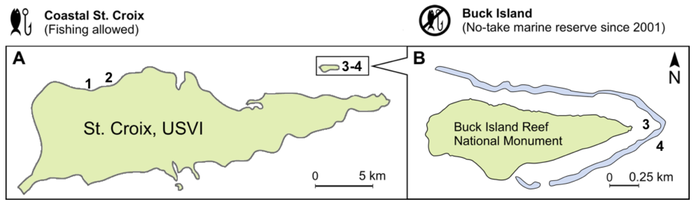
Parrotfishes feed on multiple coral species, but have high rates of focused predation on endangered *Orbicella annularis*[4-6]. If colonies do not heal from bites, parrotfish corallivory could contribute to substantial long-term declines in *O. annularis*[7,8].Yet, little is known about the processes of *O. annularis* healing and recovery following parrotfish predation.

OBJECTIVE

To quantify *O. annularis* healing rates from parrotfish bite scars based on traits of individual scars, colonies and sites on St. Croix, US Virgin Islands.

METHODS

Data collection: In July, 2018 we opportunistically tagged a total of 85 *O. annularis* colonies with fresh parrotfish bite scars across 4 sites, 2 on coastal St. Croix and 2 in the Buck Island MPA:



We measured colony surface area and depth, then photographed scars with a size reference every 3-7 days over 28 days. Using Image J, we analyzed photos to quantify change in scar surface area over time (Fig 1).

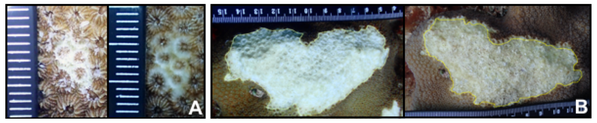


Fig. 1. Images of (A) a small scar from a single bite and (B) a large scar from repetitive, focused predation on days 1 (left) and 10 (right).

Data Analysis: We used a linear mixed effects model of scar healing (cm^2/day) in response to natural log (ln) of initial scar size, colony surface area (SA), colony relative tissue loss (total scar SA /colony SA), and colony depth and site location (Coastal St. Croix vs. Buck Island MPA), accounting for repeated measurements from scars nested within colonies over time.

RESULTS

Based on AIC_c selection, the best model included all variables except colony SA and depth, and was significantly better than the null model ($X^2_{(4)} = 282.17$, $p<0.001$). Based on marginal and conditional R^2 values, fixed effects explained 49.2% of variation in scar healing rate, while fixed and random effects explained 70.2%.

Thresholds in tissue regeneration: The largest scar that fully healed had an initial surface area of 0.894 cm^2. Overall, the percent of the initial scar area that healed after 28 days decreased as the initial scar surface area increased (Fig. 2)

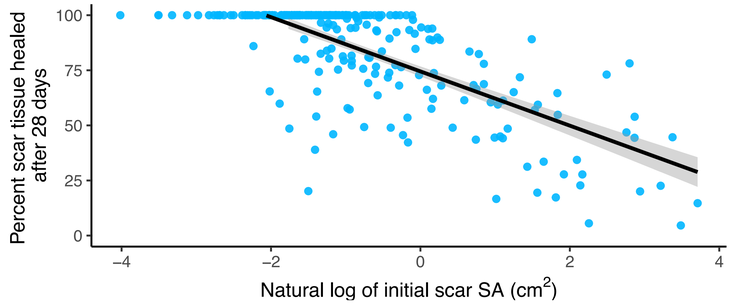


Fig. 2. Percent of the initial bite scar tissue healed after 28 days in response to natural log of initial scar surface area. Trend line shows ± SEM in gray.

Decrease in scar healing rates over time: After accounting for other fixed effects, for every 1 day increase since the scar was inflicted, scar healing rate decreased by $2.42*10^{-6}$ cm^2/day ($t_{(163.7)}= -5.808$, $p<0.001$; Fig. 3).

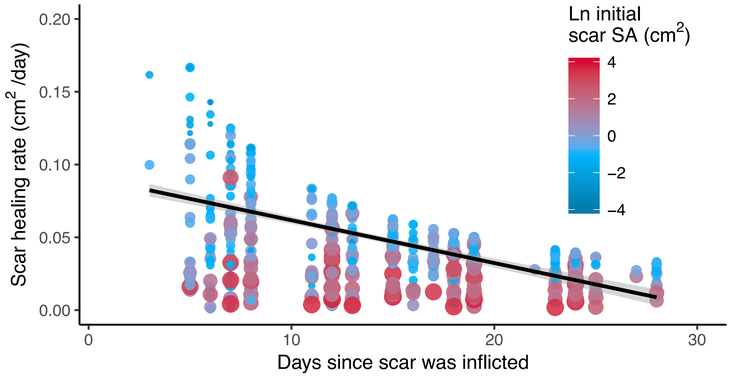


Fig. 3. Scar healing rates over time since the scar was inflicted and natural log of initial scar surface area. Larger dot size indicates larger initial scar surface area.

ACKNOWLEDGEMENTS

NOAA's Coral Reef Conservation Program and the CSU Council on Ocean Affairs, Science & Technology provided research funding. The St. Croix National Park Service provided logistical support. Cal Poly Graduate Education and the Association of Marine Laboratories of the Caribbean provided travel funding. I am grateful to Dr. B. Chance for statistical analysis consulting and M. Roycroft, M. Lippert, M. Goodman, P. Vanderbloomer and A. Wolman for their help in conducting field research.

[1] Rotjan RD, Lewis SM (2008) Impact of coral predators on tropical reefs. Mar Ecol Prog Ser 367:73–91
[2] Miller MW, Hay ME (2010) Effects of fish predation and seaweed competition on the survival and growth of corals. Oecologia 113:231–238
[3] Burkepile DE (2012) Context-dependent corallivory by parrotfishes in a Caribbean reef ecosystem. Coral Reefs 31:111–120
[4] Aronson R, Bruckner A, Moore J, Precht B, Weil E (2008) Montastraea annularis. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T133134A3592972.en
[5] Bythell JC, Gladfelter EH, Bythell M (1993) Chronic & catastrophic natural mortality of three common Caribbean reef corals. Coral Reefs 12:143–152
[6] Garzon-Ferreira J, Reyes-Nivia M (2001) Incidencia de la depredacion por peces en corales petreos de cuatro atolones del archipeielago de san andres y providencia (Caribe Colombiano). Bol Invest Mar Cost 30:133–150
[7] Mumby PJ (2009) Herbivory versus corallivory: Are parrotfish good or bad for Caribbean coral reefs? Coral Reefs 28:683–690
[8] Rotjan RD, Lewis SM (2009) Predators selectively graze reproductive structures in a clonal marine organism. Mar Biol 156:569–577

Scar healing rate decreased as initial scar area increased: After accounting for other fixed effects, for every 1 cm^2 increase in initial scar SA, scar healing rate decreased by $3.19*10^{-4}$ cm^2/day ($t_{(209.90)}= -15.341$, $p<0.001$). Colonies in the Buck Island MPA had $4.68*10^{-4}$ cm^2/day higher average scar healing rates than those on coastal St. Croix ($t_{(5.14)}= -3.672$, $p=0.0137$; Fig. 4).

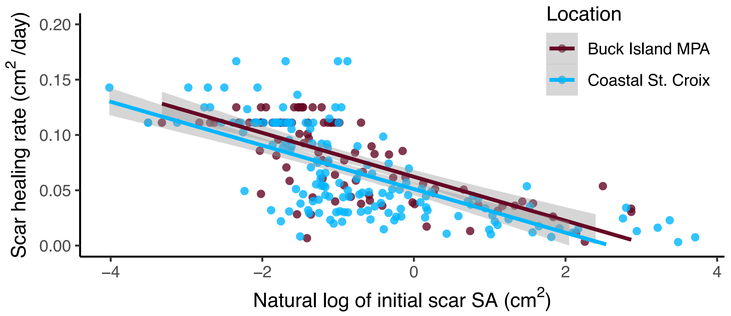


Fig. 4. Scar healing rate in response to natural log of initial scar surface area for bite scars on colonies within the Buck Is. MPA compared to coastal St. Croix.

Scar healing rates decreased as of relative colony tissue loss increased: After accounting for other fixed effects, for every 1% increase in the relative total tissue loss on a colony due to parrotfish predation, scar healing rates decreased by $1.76*10^{-5}$ cm^2/day ($t_{(381.1)}= -3.093$, $p=0.0023$; Fig. 5).

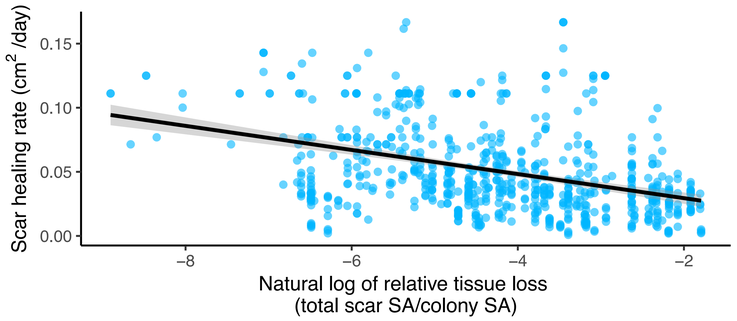


Fig. 5. Scar healing rate in response to natural log of *O. annularis* colony relative tissue loss (total scar surface area/colony surface area).

CONCLUSIONS

Summary: On average, scar healing rates decreased over time, as initial scar surface area increased, and relative colony tissue loss increased. Average scar healing was higher within the Buck Island MPA compared to Coastal St. Croix.

Future directions: In addition to monitoring *O. annularis* scar healing, we measured the standing stock of scars among reef-building corals. With these data, we will estimate differences in intensity of corallivory in response to site-level variation in parrotfish biomass and species composition, coral cover and composition, and cover of benthic organisms to quantify ecological drivers of corallivory.