PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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2014-2015 PROJECTS

RESILIENCE OF ENDANGERED ACROPORA SP. CORALS IN BELIZE. WHY IS CORAL GARDENS REEF THRIVING?:
Faculty: LISA GREER, Washington & Lee University, HALARD LESCINSKY, Otterbein University, KARL WIRTH, Macalester College
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TECTONIC EVOLUTION OF THE CHUGACH-PRINCE WILLIAM TERRANE, SOUTH CENTRAL ALASKA:
Faculty: CAM DAVIDSON, Carleton College, JOHN GARVER Union College
Students: KAITLYN SUAREZ, Union College, WILLIAM GRIMM, Carleton College, RANIER LEMPERT, Amherst College, ELAINE YOUNG, Ohio Wesleyan University, FRANK MOLINEK, Carleton College, EILEEN ALEJOS, Union College

EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SW MONTANA: METASUPRACRUSTAL ROCKS OF THE RUBY RANGE
Faculty: TEKLA HARMS, Amherst College, JULIE BALDWIN, University of Montana
Students: BRIANNA BERG, University of Montana, AMAR MUKUNDA, Amherst College, REBECCA BLAND, Mt. Holyoke College, JACOB HUGHES, Western Kentucky University, LUIS RODRIGUEZ, Universidad de Puerto Rico-Mayaguez , MARIAH ARMENTA, University of Arizona, CLEMENTINE HAMELIN, Smith College

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GEOMORPHOLOGIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA:
Faculty: KELLY MACGREGOR, Macalester College, AMY MYRBO, LabCore, University of Minnesota
Students: ERIC STEPHENS, Macalester College, KARLY CLIPPINGER, Beloit College, ASHLEIGH, COVARRUBIAS, California State University-San Bernardino, GRAYSON CARLILE, Whitman College, MADISON ANDRES, Colorado College, EMILY DIENER, Macalester College

ANTARCTIC PLIOCENE AND LOWER PLEISTOCENE (GELASIAN) PALEOCLIMATE RECONSTRUCTED FROM OCEAN DRILLING PROGRAM WEDDELL SEA CORES:
Faculty: SUZANNE O'CONNELL, Wesleyan University
Students: JAMES HALL, Wesleyan University, CASSANDRE STIRPE, Vassar College, HALI ENGLERT, Macalester College

HOLOCENE CLIMATIC CHANGE AND ACTIVE TECTONICS IN THE PERUVIAN ANDES: IMPACTS ON GLACIERS AND LAKES:
Faculty: DON RODBELL & DAVID GILLIKIN, Union College
Students: NICHOLAS WEIDHAAS, Union College, ALIA PAYNE, Macalester College, JULIE DANIELS, Northern Illinois University

GEOLOGICAL HAZARDS, CLIMATE CHANGE, AND HUMAN/ECOSYSTEMS RESILIENCE IN THE ISLANDS OF THE FOUR MOUNTAINS, ALASKA
Faculty: KIRSTEN NICOLAYSEN, Whitman College
Students: LYDIA LOOPESKO, Whitman College, ANNE FULTON, Pomona College, THOMAS BARTLETT, Colgate University

CALIBRATING NATURAL BASALTIC LAVA FLOWS WITH LARGE-SCALE LAVA EXPERIMENTS:
Faculty: JEFF KARSON, Syracuse University, RICK HAZLETT, Pomona College
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FIRE AND CATASTROPHIC FLOODING, FOURMILE CATCHMENT, FRONT RANGE, COLORADO:
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SOPHOMORE PROJECT: **AQUATIC BIOGEOCHEMISTRY: TRACKING POLLUTION IN RIVER SYSTEMS**
Faculty: ANOUK VERHEYDEN-GILLIKIN, Union College
Students: CELINA BRIEVA, Mt. Holyoke College, SARA GUTIERREZ, University of California-Berkeley, ALESIA HUNTER, Beloit College, ANNY KELLY SAINVIL, Smith College, LARENZ STOREY, Union College, ANGEL TATE, Oberlin College

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Keck Geology Consortium: Projects 2014-2015
Short Contributions— Belize Reef Project

MULTI-LEVEL CHARACTERIZATION OF ACROPORID CORAL POPULATIONS AT CORAL GARDENS, BELIZE: A REFUGIA IDENTIFIED
LISA GREER, Washington & Lee University, HALARD LESCINSKY, Otterbein University, KARL WIRTH, Macalester College

ARE THREESPOT DAMSELFISH HELPING OR HURTING THE POSSIBLE RESURGENCE OF ACROPORA CORALS?
ZEBULON MARTIN, Otterbein University
Research Advisor: Dr. Halard Lescinsky, Otterbein University

GEOEYE-1 IMAGERY CLASSIFICATION: AN ACCURATE METHOD FOR IDENTIFYING POPULATIONS OF *ACROPORA* SPP. CORALS PRIOR TO A FIELD STUDY
JAMES BUSCH**,** Washington & Lee University
Research Advisor**:** Lisa Greer, Washington & Lee University

MORPHOMETRIC AND TAPHONOMIC ANALYSIS OF *ACROPORA PROLIFERA* AT CORAL GARDENS, BELIZE
SHANNON DILLON, Colgate University
Research Advisor: Constance M. Soja, Colgate University

***ACROPORA CERVICORNIS* RUBBLE AND FOSSIL FRAMEWORK AT CORAL GARDENS, BELIZE: INVESTIGATING ENVIRONMENTAL CONDITIONS AND SAMPLING STRATEGIES USING STABLE ISOTOPE GEOCHEMISTRY**
SARAH HOLMES, Beloit College
Research Advisor: Carl Mendelson, Beloit College

QUANTIFYING THE MICRO- AND MACRO- BORING COMMUNITIES IN CORAL GARDENS, BELIZE
GABRIELA GARCIA, Oberlin College
Research Advisor: Dennis K. Hubbard, Oberlin College

GRAZER DYNAMICS ON AN ACROPORID PATCH REEF SYSTEM AND THEIR IMPLICATIONS FOR THE CARBONATE BUDGET AT CORAL GARDENS, BELIZE
SARAH K. BENDER, The College of Wooster
Research Advisor: Mark Wilson, The College of Wooster

ACROPORA CERVICORNIS CARBONATE PRODUCTION AT CORAL GARDENS, BELIZE: PREDICTING FUTURE REEF STABILITY
ERIN PEELING, The Pennsylvania State University
Research Advisor: Tim Bralower, The Pennsylvania State University

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USING SEDIMENTS AND SUBSTRATES TO INTERPRET REGIONAL HYDRODYNAMICS AND ECOLOGY OF CORAL GARDENS, BELIZE
GREGORY MAK, Trinity University
Research Advisor: Daniel J. Lehrmann, Trinity University

GROWTH PATTERNS OF ACROPORA CERVICORNIS AFFECTED BY CURRENTS AT CORAL GARDENS, BELIZE
THOMAS R. HEROLD, The College of Wooster
Research Advisor: Shelley Judge, The College of Wooster

INVESTIGATIONS OF RESILIENT ACROPORA COMMUNITIES IN BELIZE: RELATIVE AGING AND INTRASPECIFIC DIVERSITY CALCULATIONS OF SPECIES USING MICROSATELLITE MARKERS AND SOMATIC MUTATIONS
ADELE IRWIN, Washington and Lee University
Research Advisor: Lisa Greer, Washington & Lee University

RECORD OF ENVIRONMENTAL CHANGE IN CARRIBEAN CORAL REEFS: SCLEROCHRONOLOGY AND GEOCHEMISTRY OF *O. FAVEOLATA* AS A PALEOCLIMATE PROXY AT CORAL GARDENS AND ROCKY POINT, BELIZE.
ILIAN A. DECORTE, Macalester College
Research Advisor: Karl R. Wirth, Macalester College

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ARE THREESPOT DAMSELFISH HELPING OR HURTING THE POSSIBLE RESURGENCE OF ACROPORA CORALS?

ZEB MARTIN, Otterbein University
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INTRODUCTION

Stegastes planifrons, the threespot damselfish, is a notorious territorial herbivorous fish that has been shown to have both negative and positive impacts on the growth of *Acropora cervicornis,* its preferred habitat. The most noted effect is a chimney-like scar caused by the fish nipping at live coral tissue creating a dead spot that allows the growth of its food – filamentous algae. This behavior may cause partial mortality of the coral (Kaufman 1977; Knowlton et al. 1990; Lirman et al. 2010) and decrease in the number of individuals and colony size of *A. cervicornis* (Knowlton et al. 1990) Lirman et al. (2010) point to the gardening activities of damselfish as one of three major stressors on an *A. cervicornis* dominated reef off the coast of the Dominican Republic. They found that up to 25% of colonies showed adverse signs of damselfish activities, including major live coral tissue loss. Damselfish may also have a negative effect on reefs by carrying off sea urchins that would otherwise help control the growth rate of algae on the reef (Williams 1979).

However, *Stegastes planifrons* also has indirect positive effects on the growth of *A. cervicornis* (Williams 1980; Sammarco 1983; Irving & Witman 2009; Gochfeld 2010; Precht et al. 2010). The fish may protect the reef structure by actively removing bioeroding sea urchins from the coral (Irving & Witman 2009). Williams (1980) suggested that *S. planifrons* might actually be a keystone species of coral reefs because the threespot damselfish maintain a balance between different echinoid species within the benthic community. Precht et al. (2010) also found that threespot damselfish help with maintaining the balance of corals on Caribbean coral reefs. Following the *Acropora* die off damselfish switched to *Orbicella* for habitat and had strong negative impacts on that coral's heath. They conclude the *Acropora cervicornis*-*Stegastes planifrons* connection may take decades to re-establish.

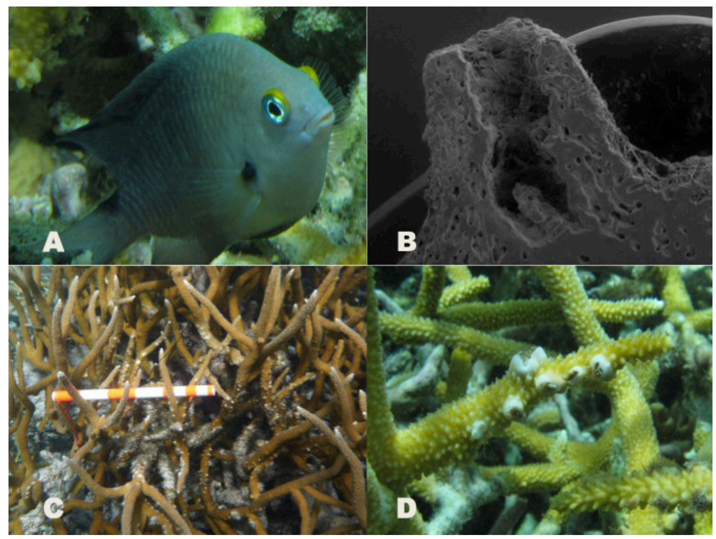

Figure 1. Examples of threespot damselfish and their chimney scars A. Stegastes planifrons (threespot damselfish) B. SEM cross-section of a chimney scar C. Algal lawn within a threespot damselfish territory D. Close up of chimney scars on live A. cervicornis

Threespot damselfish also increase the diversity of algal species within their territories, which may increase nitrogen fixation (Sammarco 1983). This would allow corals to grow faster and accrete more carbonate. Gochfeld (2010) found that territorial damselfish might inadvertently provide defense for their host corals, which may allow enhanced coral growth and survival rates within the territory of the resident threespot damselfish. However, this study from the Pacific may not be applicable to the Caribbean because of its low biodiversity of corallivorous fish. Johnson et al. (2011) however, found that threespot damselfish actually attracted other fish to staghorn corals through their farming. Despite the territorial behavior of the farming threespot damselfish they found no negative effect on local fish species abundance.

Since threespot damselfish are reported to have both positive and negative effects on *A. cervicornis*, this study sought to find what the overall net impact was for the larger more healthy patches of staghorn coral at Coral Gardens (Figure 1, Greer et al., this volume). Furthermore, this study sought to quantify the effects from threespot damselfish on the patch edges to give a fuller understanding of the smaller patches that have now become commonplace throughout the Caribbean. This is important because while *Acropora cervicornis* remains an endangered species, it is starting to rebound and the stressors that are limiting this resurgence need to be better understood. Additionally, in some areas of Belize, damselfish populations have been found to be decreasing as part of a trophic cascade related to overfishing (Mumby et al. 2012) and the impacts from this are not well known.

METHODS

Data were collected from 6 transects, between 14 and 38 meters long, through the centers of *Acropora cervicornis* patches and for 57 one m^2 quadrats along the edges of the patches. A digital photograph was taken for each one m^2 of the transect, or the edges to determine benthic cover. In addition, two divers counted and assigned a size class (small (0-20mm), medium (20-40mm), or large (40-60mm)), to each *Echinometra viridis,* reef urchins, within the quadrat. Damselfish (*S. planifrons*, *Stegastes fuscus*, and *Microspathodon chrysurus*) and their chimney scars were also counted within the quadrat.

Photoquadrats were analyzed using Coral Point Count (CPCe), image analysis software designed specifically for calculating percent cover using a point count approach. This allowed for the percent cover to be calculated for live coral cover, macroalage, and hard substratum. Additional image analysis of the quadrat photos was completed using the Habitat Assessment Score (Gratwicke & Speight 2005) to estimate structural complexity of the reef. The HAS method uses a visual key to assign a 1-5 score to five individual factors of habitat heterogeneity (rugosity or 3-D structure, height of structure, diversity of refuge sizes, percent live coral cover, and percent hard substratum). Aggregated data was further analyzed using linear regression to find specific ecosystem relationships.

RESULTS

The average number of threespot damselfish over the six live coral cover transects was 1.89 per m^2, with the highest transect average at T1 at 2.31 fish per quadrat (Table 1). The average percent live coral cover over the same transects was 38.09%. The highest coral cover average came from T5 at 48.83%. Total average number of sea urchins over transects T1-T5 was 17, while T4 had the highest average at 36 urchins per quadrat. No urchin data was collected from T6. The relationship between these three data inputs from the six transects (Fig. 2a) shows that both threespot damselfish and sea urchins have a strong negative correlation with each other as the percent live coral cover decreases.

Across the six transects the averaged percent macroalgae was 11.76%, with the highest average coverage on T4 at 16.30%. Comparing the abundance of threespot damselfish and urchins to percent macroalgae cover reveals a stronger correlation with the urchin population than that of the threespot damselfish present (Fig. 2b). This correlation can be seen when looking at T4, which had the highest average number of urchins and the highest percent of macroalgae cover per quadrat. This relationship is contrasted when comparing T5, which had the lowest number of urchins as well as the lowest percent of macroalgae.

The average chimney count for transects 1-6 was 18, with the greatest average over T6 at 63. Comparing the data collected from the edge photo-quadrats the largest average number of chimney scars (22) for all quadrats was found to be in the 0-3 meters range from the edge of the patch. While the smallest average (10) number of chimney scars per quadrat was found to be in the area ≥ 6m from the edge of the patch (Fig. 4).

The HAS analysis method yielded some very unexpected relationships. There was no relationship between threespot damselfish and the overall habitat heterogeneity across any of the of the transects (Fig. 4a), but there were patterns in three of the HAS sub-scores. The first was the lack of correlation to hard substratum suggesting that this was not driving abundance for either threespot damselfish or urchin populations. The second was little relationship to rugosity, which was surprising since *A. cervicornis* has high rugosity and is the preferred habitat of threespot damselfish. The third surprising relationship was a very strong negative correlation with the diversity of refuge sizes. Showing that the threespot and urchins both strongly prefer the smaller size class of refuge (Figure 4c).

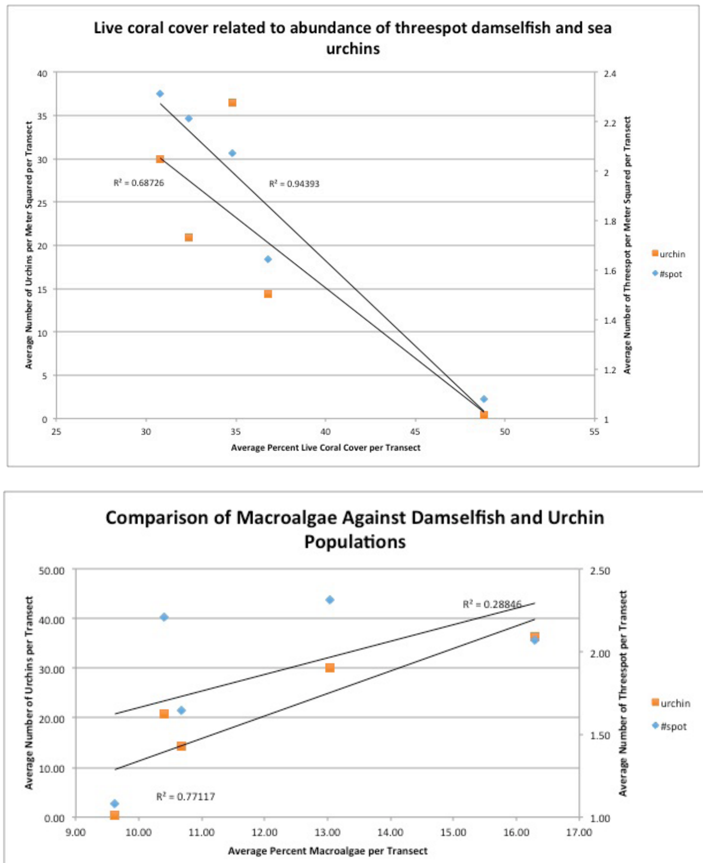

Figure 2. A. Transect level correlations Echinometra viridis (reef urchin) and Stegastes planifrons (threespot damselfish) are positively correlated with each other, but are negatively correlated with live coral cover of Acropora cervicornis. B. Threespot damselfish and urchins positively correlate with the amount of percent macroalgae cover.

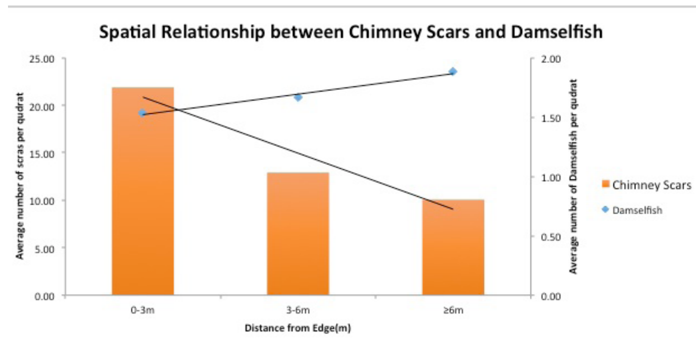

Figure 3. Impact of distance from edge on chimney scar occurrence was significantly more in quadrats near (0-3m) patch edges even though these quadrats had the fewest threespot damselfish.

	HAS Data - Averages per M^2							Transect Data - Average per m^2				
Transect	Rugosity	Growth Forms	Height	Refuge	Live %	ard Substratu	Total HAS	Threespot	Chimney	Urchin	Live %	Macroalgae
1	2.09	1.78	1.94	1.63	1.03	2.69	11.16	2.31	5.84	29.98	30.78	13.04
2	2.87	2.06	2.29	2.74	2.48	1.10	13.55	1.65	11.00	14.39	36.79	10.69
3	2.63	1.89	2.11	2.32	2.16	1.26	22.37	2.21	15.16	20.87	32.38	10.40
4	2.57	2.00	1.79	1.86	2.29	1.36	19.36	2.07	4.57	36.46	34.80	16.30
5	4.05	1.34	3.89	3.76	3.00	1.26	17.32	1.08	6.58	0.41	48.83	9.62
6	3.33	2.33	2.00	2.67	2.67	1.00	14.00	2.00	63.44	0.00	44.97	10.51
Averages	2.93	1.90	2.34	2.49	2.27	1.44	16.29	1.89	17.77	17.02	38.09	11.76

Table 1. Summary data for each transect. Data are the averages for all quadrats in a transect. Overall averages are listed beneath each column.

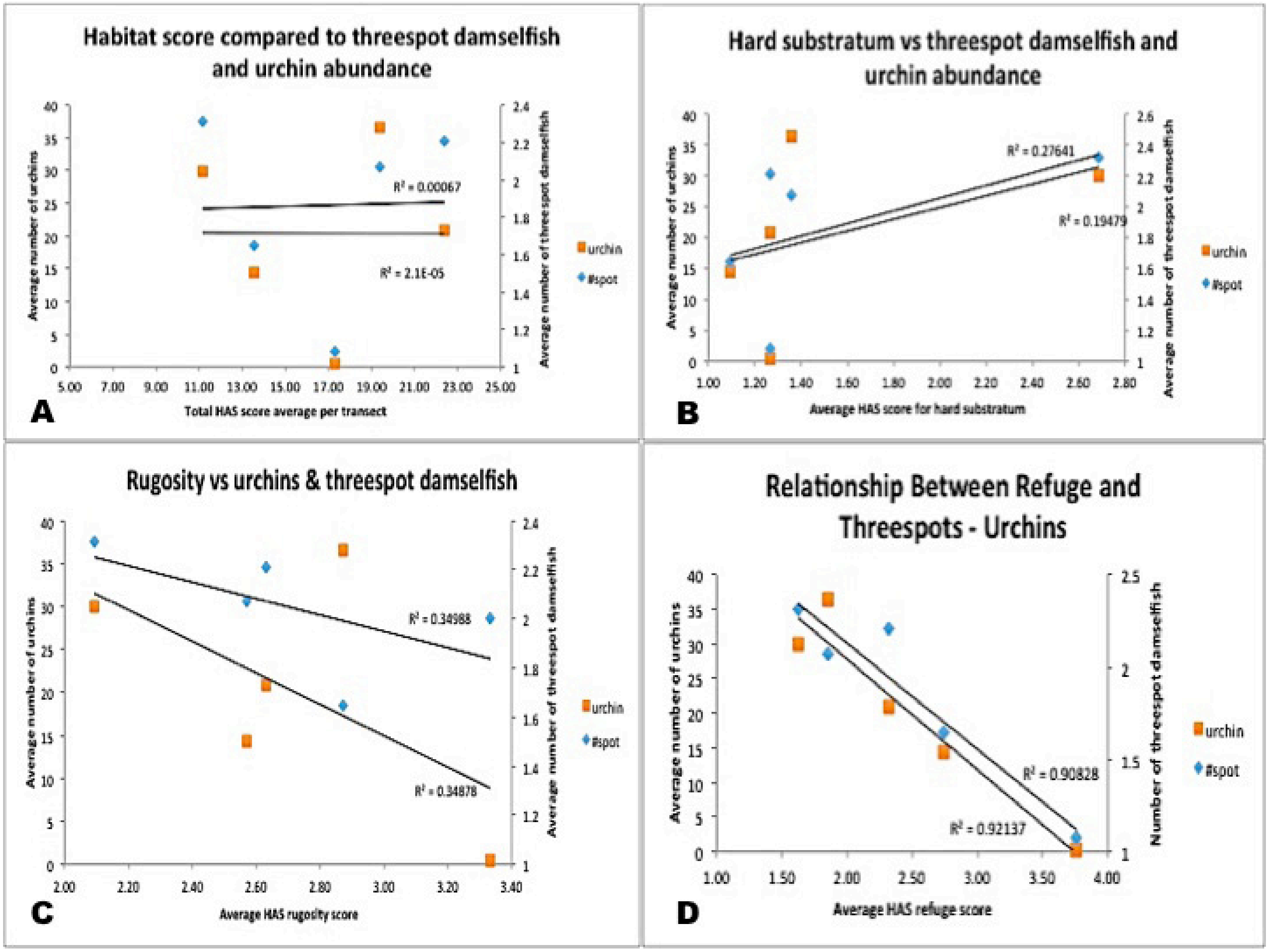

Figure 4. Results of habitat heterogeneity analysis (HAS) A. Threespot damselfish and urchin populations do not correlate with overall habitat heterogeneity. B. Except for T1 abundance of the two populations are heavily weighted towards low hard substratum. C. All transects had rugosity between 2 and 3.4 and this level was found to not correlate with fish or urchin numbers. D. A strong negative correlation between fish and urchins was found with the number of size categories of refuge. Urchins and fish are more abundant where the refuge size if uniformly small. A high diversity of refuge sizes would include larger refuges that would not provide the assumed protection needed.

DISCUSSION

The positive correlation between threespot damselfish and urchin populations is at odds with previous reports that threespot damselfish carry urchins out of their territories. Our study suggests that threespot damselfish may not effectively remove the urchins and therefore threespot damselfish do not drive the abundance of the urchins as suggested by Williams (1979) and Irving & Witman (2009). Our data alternatively suggest that the urchin population is driven by the amount of macroalgae available (Fig. 2b).

By studying threespot damselfish at Coral Gardens, with its larger healthier patches, this study was able to get a rare glimpse at their effects on *Acropora cervicornis.* The data collected for this study shows a significant negative correlation between live coral cover and threespot damselfish. This negative correlation may arise because threespot damselfish are killing the available live coral tissue to make new algal gardens. However, our data do not support this hypothesis because there is no increase in chimney scars with higher threespot damselfish abundance (Fig 3).

An alternative hypothesis is higher numbers of damselfish in areas with lower live coral cover results from habitat characteristics such as smaller refuges and more area for algal growth. If damselfish are responding to habitat characteristics, they are not keystone species as proposed by Williams (1980). High live coral cover may discourage damselfish by having larger open spaces that are less effective as refuges and decreasing available space for macroalgae.

The implications from this study are valuable. Since our data suggests that the threespot damselfish is not a keystone species, this means they are not driving the amount of live coral cover. In fact the opposite is probably true in that the percent live coral cover is controlling the abundance of threespot damselfish present on the reef. This is important in light of a recent seven-year study in Belize by Mumby et al. (2012) that found damselfish populations had fallen by up to 43% due to trophic cascades caused by overfishing. While overfishing will remain a concern for marine park managers for other reasons the data from this study helps eliminate the need for marine park managers to be concerned with maintaining or controlling threespot damselfish populations on the reef.

CONCLUSION

This study examined a "healthy" *A. cervicornis* patch reef system in order to quantify the net impact of *Stegastes planifrons* on the possible resurgence of Staghorn coral. We conclude that there is little to no significant negative impact from damselfish on the reefs in this area. However, since the main incidence of gardening scars occurs at the patch edges while the largest abundance of fish was found to be in the center of the patch, we conclude that the impact of *Stegastes planifrons* may be greater elsewhere in the Caribbean where fragmented patches have become the norm. Our data also shows a strong positive relationship between threespot and urchin abundance. This suggests that previous reports of negative and positive (Williams 1979, Irving & Witman 2009) effects of threespot damselfish on reefs via the removal of bio-eroding urchins from their territories may also be negligible. This research suggests no strong relationships exist to show that threespot damselfish are neither helping nor hurting the overall possible resurgence of *Acropora cervicornis*.

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