The Rufford Foundation
Final Report

Congratulations on the completion of your project that was supported by The Rufford Foundation.

We ask all grant recipients to complete a Final Report Form that helps us to gauge the success of our grant giving. The Final Report must be sent in **word format** and not PDF format or any other format. We understand that projects often do not follow the predicted course but knowledge of your experiences is valuable to us and others who may be undertaking similar work. Please be as honest as you can in answering the questions – remember that negative experiences are just as valuable as positive ones if they help others to learn from them.

Please complete the form in English and be as clear and concise as you can. Please note that the information may be edited for clarity. We will ask for further information if required. If you have any other materials produced by the project, particularly a few relevant photographs, please send these to us separately.

Please submit your final report to jane@rufford.org.

Thank you for your help.

Josh Cole, Grants Director

Grant Recipient Details	
Your name	Justin Baumann
Project title	Characterizing coral acclimation on the Belize Barrier Reef System using thermal history and holobiont physiology: Implications for Climate Change
RSG reference	15802-1
Reporting period	June 20th 2014 - June 20th 2015
Amount of grant	£5000
Your email address	baumannj@live.unc.edu
Date of this report	3/30/2014

1. Please indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Survey 15 coral reef sites in Belize			X	I identified 15 areas of interest in back reef and near shore areas in Belize based on sea surface temperature data. We only found coral in 13 of these areas. Rigorous coral surveys were completed at all 13 sites. Data from these surveys is currently being analysed and will be presented at the Benthic Ecology Meeting in March 2015.
Test video transect equipment in the field and record surveys			X	Video surveys were performed at all 13 sites. We designed and built affordable survey equipment with Rufford Foundation funding and field tested it successfully. These data will be analysed over the coming months and combined with diver survey data (above) to create a robust data set for reef health and differences in habitat structure on patch reefs in Belize.
Collect seawater for nutrient analysis			X	Ten seawater samples were collected at each of the 13 sites. These samples will be analysed for Total Nitrogen in order to better understand how nutrient concentrations may alter community structure. These samples will be analysed in January and February 2015.
Collect small coral subsamples for symbiont identification and host genetics			X	Ten subsamples of four different species were collected at all 13 sites (except when one of the four target species was not present). These samples have been preserved and will be used to identify dominate symbiont types in each species across environments. We also plan to use these samples to understand how host gene expression may change with temperature and environment. These samples will be processed in December 2014 and January 2015.

Develop a documentary video showcasing this research			X	We brought an undergraduate communications and biology major to the field with us. He shot hours of video, interviewed all of us, and some locals, and has produced a short video of from the trip (submitted to the Beneath the Waves Film Festival: https://www.youtube.com/watch?v=cBYvBWwH_tA). He is currently working on a longer documentary from the trip, which will serve as part of his undergraduate thesis project.

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled (if relevant).

Acquiring proper CITES and research permits from Belize Fisheries proved to be difficult. We travelled to Belize around a national holiday (Garifuna Settlement Day, Nov 19th). When we got to Belize on November 14th, our contact in the fisheries office was sick. He was then off for a few days during the holiday and we had a hard time getting a permit because he was in charge of permits, but he was not around. Our permits were approved in writing (via email) by the Fisheries Department, so we continued our research as planned. We contacted fisheries by phone while we were in the country and worked out a day and time to sign the paperwork and everything was in order by the time we left the country. We had all of the appropriate documentation and were able to export out samples out of Belize and into the US without trouble.

Our other major difficulty was locating coral in some of our site locations. I chose patch reef sites based on a GIS map that had rough estimates of coral locations on it, combined with sea surface temperature data that I extracted from a NOAA satellite product. Areas that had reefs (or were near reefs), that also had extreme, moderate, or low temperature variability were identified with a series of GPS coordinates. My advisor, Dr Karl Castillo is a Belize native and has a great deal of experience with reefs in southern Belize, so we knew we could find corals in all of our southern sites. However, we were not sure if we could find corals in our central and northern sites. Luckily, we had arranged transport with a series of experienced local fishing/diving captains who knew the reefs, cayes, and channels much better than we did. On three separate occasions our various captains were able to locate corals in areas where there are not many reefs, including one site that was about 30 m from the mainland in an undeveloped area. Without our local captains we would not have been anywhere near as successful with our research.

3. Briefly describe the three most important outcomes of your project.

1) The lagoonal reefs along the Belize barrier reef system were classified. Based on thermal regime (variability + max temperature) there are three distinct lagoonal reef environments in Belize (low variability and low temperature, moderate variability and

moderate temperature, and extreme variability and hot temperature) (Fig 1). Utilizing data from NASA JPL MUR SST products, I created a metric to classify areas of the reef based on four factors: annual temperature variability, annual maximum temperature, annual days above the bleaching threshold (29.7 °C), and annual consecutive days above the bleaching threshold. Each of the four factors was binned based on standard deviation (within 1 SD of mean was "moderate", >1 SD above mean was "extreme", and >1 SD below mean was "low"). Data from the four factors were overlaid and if all four factors classified as "moderate" in an area, that area was designated "moderate." The same held true for "low" and "extreme" sites (Fig. 1).

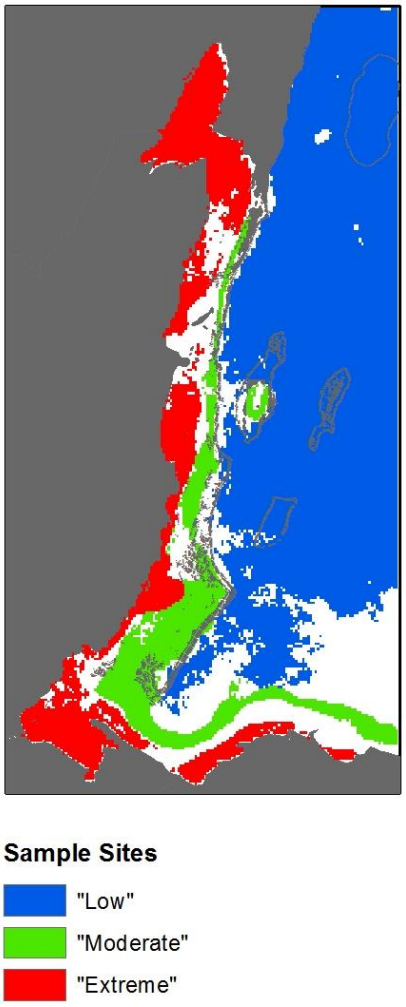

Figure 1: Thermal environments on the Belize Barrier Reef System. Low (blue), Moderate (green), and extreme (red) environments were classified based on satellite SST analysis by J. Baumann.

2) "Extreme" sites are significantly less diverse and have lower species richness and abundance (Fig 2). In spite of having measurably different thermal regimes, "low" and "moderate" sites have very similar species diversity and richness. "Extreme" sites are much less diverse. The result indicates that temperature and temperature do play a

role in community composition, but that there is likely some threshold at which many coral species can no longer cope. Only about 10 species of coral exist at "extreme" sites relative to "low" and "moderate" sites. These corals may be more resilient to temperature stress and thermal variability. Moving forward, understanding the mechanisms that allow these corals to survive where other cannot will be the main focus of this project.

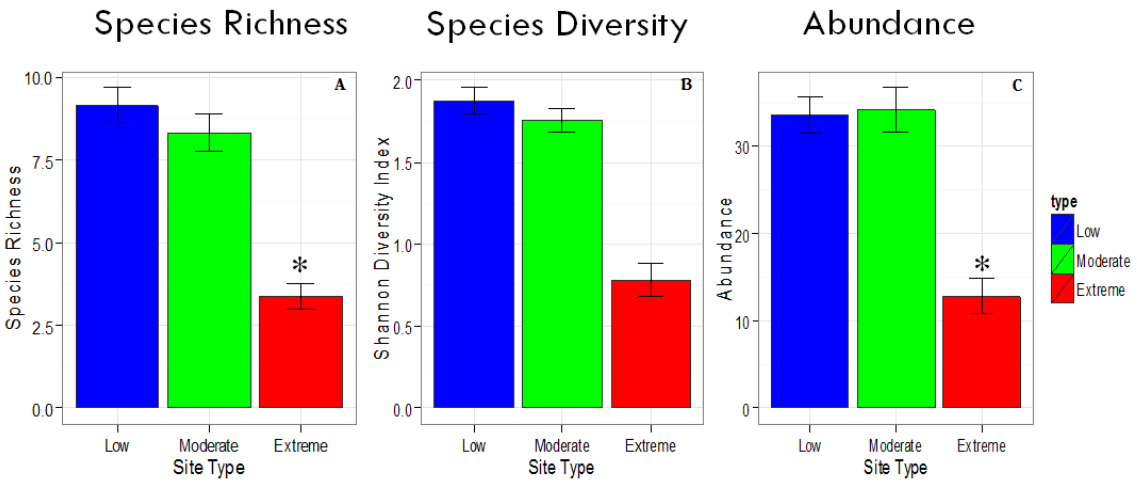

Fig 2: A: Species Richness by site type, B: Species Diversity by site type, C: Abundance of coral by site type

3) While overall carbon to nitrogen ratios do not vary between site types, there is evidence that some nutrient concentrations differ greatly by site type. Dissolved organic carbon (DOC) is highest at "extreme" sites and has previously been suggested to have a negative impact on corals (Fig. 3). Nutrient measurements are preliminary, but understanding how macro and micro nutrient concentration differ across the BBRS, and how these concentrations affect corals, is an important part of future research. Recently, bulk satellite chlorophyll a (chl a) data have been extracted for NOAA ERDAAP. Over the last decade it is clear that each site type differs in terms of chl a (a proxy for nutrients) (Fig. 4). This remote data has helped put our nutrient spot measurements into context. In fact, the extreme sites, which experience the hottest temperatures and the highest annual variation in temperature also experience the highest bulk nutrient concentrations and the highest DOC values. DOC is a type of nutrient that has previously been shown to be detrimental to coral health. The extreme sites have fewer corals and lower diversity than low and moderate sites, which makes sense given this context. However, it is yet unknown how the surviving corals are effected. Measuring growth rate and performing tank experiments using corals from all three site types will prove most valuable to understanding the physiological reasons behind how corals live in extreme sites.

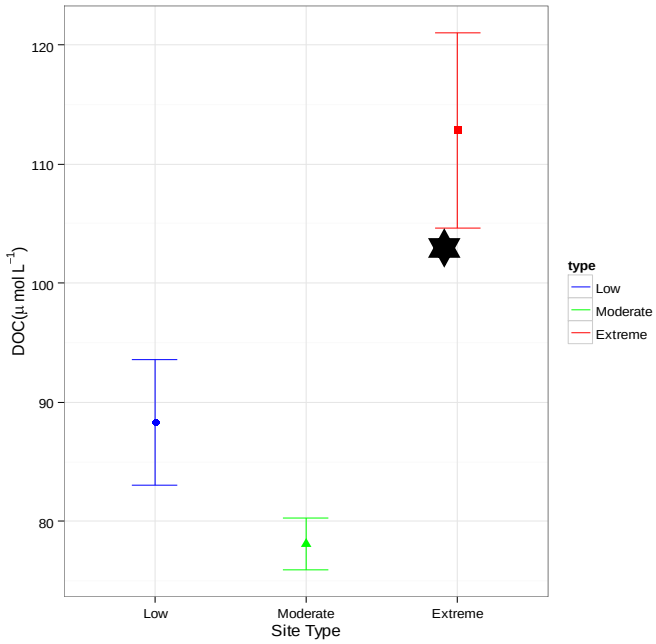

Figure 3: DOC by site type

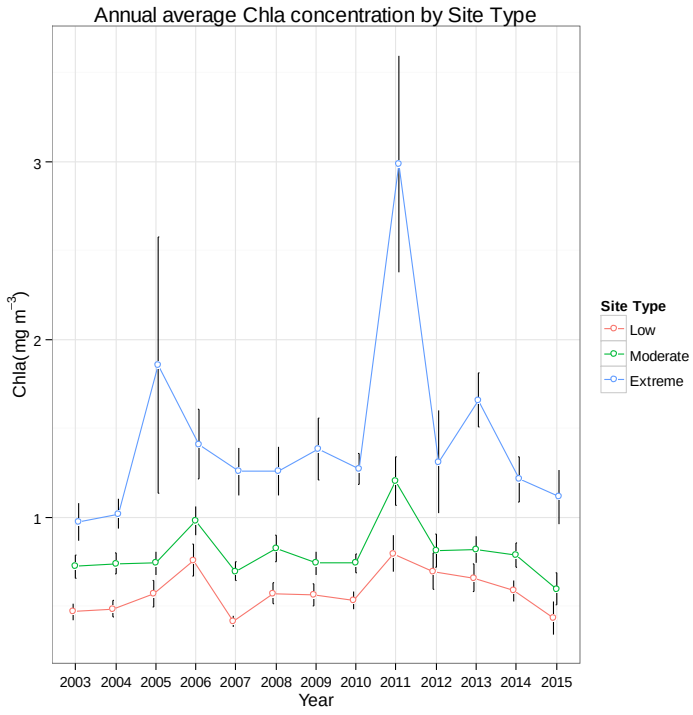

Figure 4: Annual chl a concentrations (mg/m^3) by site type.

4. Briefly describe the involvement of local communities and how they have benefitted from the project (if relevant).

We were assisted by local people every step of the way in this project. In Placencia, Dangriga, and Punta Gorda we worked with "Garbutt's Fishing Lodge" to charter boats and captains. They are a local, southern Belizean run business and all of them were extremely knowledgeable about the water and the reefs. Our boat captains helped us find corals in nearshore areas with high sedimentation and low visibility (places we never should have found corals). Additionally, they navigated the coastal waterways expertly and got us where we needed to be without any trouble. Eworth, one of the owners is a long time fishing guide and a local expert on the Sapodilla Cayes. He has served on the board of the Sapodilla Cayes marine reserve. These locals are mainly fishing guides, but they understand how important protecting the reef is and they went out of their way to make sure we were able to get our research done.

In addition to working with Garbutt, we also stayed at locally owned hotels and inns in every city we stopped in (Punta Gorda, Placencia, and San Pedro). We hired a local boat captain in San Pedro as well. In the past similar research has been done by renting a live-aboard vessel and boating to and from each reef site without much interaction with the coastal people. Our interest in Belize goes beyond the scientific. Dr Castillo wants to help the country that he grew up in protect its coral reefs and build its economy. I am a firm believer in experiencing the local culture of any area I travel to, let alone work in. With these two values in mind, we decided to do this trip in a more interactive way. We stayed in local spots in town, we ate the local food, and we talked with the local people. We were able to drive the Belizean roads, se the jungle and the citrus valley and really understand the economy and lifestyle of the country. Interestingly enough, this approach actually saved us money (renting a large boat is expensive). I am planning to conduct future trips to Belize in the same fashion.

5. Are there any plans to continue this work?

I intend to continue this work by analysing the data that we collected this year. I presented preliminary findings at The Benthic Ecology Meeting in March 2015, and am working on writing a paper to be submitted to a peer-reviewed journal by autumn 2015. We will continue field research into coral acclimatization ability in summer/autumn 2015 by returning to our sampling sites. In 2015 we will core at two species of coral (*S. sidereal* and *P. strigose*) per site to reconstruct thermal history and correlate it to satellite temperature records. We will also begin a reciprocal transplant experiment by transplanting corals (*S. sidereal*, *P. astreoides*, *P. strigose* and *S. radians*) from areas of high temperature variability to areas of moderate and low variability, and vice-versa. The goal is to see how corals respond to different temperature regimes and different maximum temperatures. From our preliminary study, we know that coral cover and species composition change between these three types of sites. Soon we will have an idea of how endosymbiont communities are different between sites (lab work underway now). Adding all of this together with the results of the reciprocal

transplant experiment will allow me to make robust conclusions about how thermal regimes and thermal stress can alter communities in Belize. These results should prove useful to local NGOs and managers who are looking to make informed policy decisions.

6. How do you plan to share the results of your work with others?

This work was presented at the Benthic Ecology Meeting in March 2015. Additionally, the results of this project will be submitted to a peer-reviewed academic journal in autumn 2015. A short documentary about this project and the importance of coral reef research has been produced by our lab and a longer documentary is in production now (to be shared with several marine science film organizations). A trip recap complete with pictures and first-hand accounts is posted on my marine science education blog (underthecblog.wordpress.com).

7. Timescale: Over what period was The Rufford Foundation grant used? How does this compare to the anticipated or actual length of the project?

The grant was used from June 20th 2014 until December 1st 2014. Supplies and lodging were purchased with the funds from June 2014- November 2014. The field portion of the project occurred from November 14th 2014 - November 25th 2014. A few final expenses were paid after this date. The project began in June 2014 and due to the initial success, will continue until 2017.

8. Budget: Please provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used.

USD to Pound Sterling conversion= 0.60. All reported costs are in Pounds Sterling

Item	Budgeted Amount	Actual Amount	Difference	Comments
Flights	1787	1122.51	+664.49	I bought flights for two people instead of four. Lab start-up covered the other field technicians.
Boat Rental	3000		+3000	Boat rental was paid with lab start-up
Crew Salary	192		+192	Crew costs were paid from lab start-up
Travel Insurance		105.41	-105.41	
Lodging		474.86	-474.86	
San Pedro Water Taxi		90.17	-90.17	Unexpected expense. We had to travel on this water taxi more than planned due to inability to secure a private vessel.

Temperature and Light Loggers	0	1319.54	-1319.54	Semi-permanent temperature and light logging devices were placed at all sites, as planned. We thought we had enough left over loggers from previous field seasons for this project, but we did not. I purchased more and we used these loggers for our study this year.
GoPro equipment		997.734	-997.734	GoPro cameras were part of the original costs, but they were projected to be purchased with different funds. Those funds were allocated to flights and boat rental instead due to a freeze on purchasing at UNC (caused by a software switch). Rufford funds were easily accessible during this time so many items were purchased using this account in place of the lab start-up account. In return, the lab account covered costs for flights and boat rental.
Scuba gear, field equipment, survey equipment, expendable items		639.78	-639.78	Many of these items were unexpected costs, but some were part of the original costs and were planned to be purchased with different funds. Those funds were allocated to flights and boat rental instead due to a freeze on purchasing at UNC (caused by a software switch). Rufford funds were easily accessible during this time so many items were purchased using this account in place of the lab start-up account. In return, the lab account covered costs for flights and boat rental. Example items include: waterproof paper, coral ID charts, extra rope and rigging (necessary for survey gear and

				temperature loggers),
Belize Fisheries Collection and CITES permits	0	250.00	-250.00	At the time of grant submission, we did not know how much this would cost, so we left it out.
Total	4979	**4996.99**	17.99	Additional costs include roughly £10,000 worth of travel, lodging, and food expenses that were covered by lab start-up.

9. Looking ahead, what do you feel are the important next steps?

Analysing the data and samples we have already collected is the most crucial next step. Following these analyses, I will move forward with the next phase of the project, which is coring corals at our sites and beginning a reciprocal transplant experiment as mentioned above.

10. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the RSGF receive any publicity during the course of your work?

The Rufford Foundation logo appears on my personal, professional webpage (jbaumann3.wordpress.com). It appeared on my departmental seminar and Benthic Ecology Meeting 2015 presentation. It will also appear on all other papers and presentations related to this project. As this is part of my PhD dissertation, the logo will appear on all related documents and presentations until I graduate. RSGF has received some publicity already, as I have shared the application with all graduate students in my department and have encouraged other colleagues to apply. I have also featured RSGF in a blog post that I wrote about this research on underthecblog.org. Lastly, RSGF will receive more publicity when the short documentary film about this field season is finalized.

11. Any other comments?

I have learned a great deal about the cultural melting plot that is Belize this autumn. They rely on the reef for a great deal of their GDP, be it through fishing or tourism, which are clearly two major factors in their coastal economy. I am thankful for the help of passionate local guides and captains who helped us find our research sites. Coral research is something that the average person in coastal Belize is interested in. Many folks talked with us about our work and resort and hotel owners were kind enough to offer us significant discounts to stay with them. Without their kindness, and the support of RSGF, this trip would not have happened. I am very passionate about conservation and climate science and I look forward to continuing my work. It will be more than just an intellectual exercise. This project will have a direct impact on how we think about coral's ability to acclimatize to different temperature regimes. Ultimately, I hope to provide managers basin wide with practical suggestions and guidelines to improve the structure of marine protected areas and strengthen and update conservation policy.